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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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TERRAPOWER NATRIUM DESIGN CENTER SUBCOMMITTEE

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TUESDAY

MARCH 18, 2025

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The Subcommittee met via Video/ Teleconference, at 8:30 a.m. EDT, Thomas E. Roberts, Chair, presiding.

COMMITTEE MEMBERS:

THOMAS E. ROBERTS, Chair
RONALD G. BALLINGER
VICKI M. BIER
VESNA B. DIMITRIJEVIC
GREGORY H. HALNON
CRAIG D. HARRINGTON
ROBERT P. MARTIN
SCOTT P. PALMTAG
DAVID A. PETTI
MATTHEW W. SUNSERI

ACRS CONSULTANT:

STEPHEN P. SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

KENT L. HOWARD, SR.

ALSO PRESENT:

REED R. ANZALONE, NRR/DANU/UTB2

JOSH M. BORROMEO, NRR/DANU/UAL1

ROEL BRUSSELMANS, NRR/DANU/UTB2

MIKE JARRETT, TerraPower

NICK KELLENBERGER, TerraPower

HUGH LUO, TerraPower

EDWIN LYMAN, Union of Concerned Scientists

ALEC J. NELLER, NRR/DANU/UTB2

SCOTT PFEFFER, GE Vernova

JOSH RICHARD, TerraPower/GE Vernova

RICHARD SCHULTZ, TerraPower

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

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

8:30 a.m.

CHAIR ROBERTS: Good morning, this meeting will now come to order. This is a meeting of the TerraPower Natrium Design Center Subcommittee and the Advisory Committee on Reactor Safeguards. I am Tom Roberts, chairman of today's subcommittee meeting. ACRS members in attendance in person are Ron Ballinger, Greg Halnon, Craig Harrington, Robert Martin, Scott Palmtag, Dave Petti, and Matthew Sunseri, and myself.

ACRS members in attendance virtually via Teams are Vesna Dimitrijevic and Vicki Bier. We have our consultant participating virtually, Steve Schultz, and if I have missed any members or consultants, please let me know now. Okay, Kent Howard of the ACRS staff is the designated federal officer for this meeting.

No member conflicts of interest were identified for today's meeting, I know we have a quorum. During this meeting the subcommittee will receive a briefing on four Natrium topical reports over a two day period. I want to start with an overview of where we are in our review and the nature of the application.

The staff is currently reviewing the construction permit application submitted by TerraPower in March of last year, and they will be presenting the results of that review to us starting in late summer, early fall of this year. So, the construction permit application is not the subject of this meeting.

Rather TerraPower had submitted 11 foundational topical reports in advance of their construction permit application, and the staff takes action on them separately from the construction permit application. We reviewed topical reports when warranted to maximize priority alignment between all parties, and to reveal safety concerns as early as possible in the process when they are easier to resolve.

For this project we previously reviewed five topical reports, identified two that did not warrant our review, and we have reviewed the remaining four early topical reports at this meeting. The four topical reports cover a wide range of topics, and we will rely on our subject matter experts to lead the subcommittee discussions on them.

Today we'll cover the methodology for analysis of design basis accidents that occur within the reactor vessel and do not result in a radiological release led by Bob Martin, and the methodology of our nuclear stability analysis led by Scott Palmtag. We'll cover the other two topical reports tomorrow. The ACRS was established by statute and is governed by the Federal Advisory Committee Act, or FACA.

The NRC has issued regulations to implement FACA, per these regulations and the committee's bylaws, the ACRS speaks only through its published letter reports. All member comments will be regarded as only the individual opinion of that member, not a committee position. All relevant information related to ACRS activities such as letters, rules for meeting participation, and transcripts are located on the NRC public website.

And can easily be found by typing about us ACRS in the search field on NRC's homepage. The ACRS, consistent with the agency's value in public transparency and regulation of nuclear facilities provides opportunity for public input and comment during our proceedings. We received no written statements or requests to make an oral statement from the public.

We have set aside time at the end of this meeting for public comments. Portions of this meeting may be closed to protect sensitive information as required by FACA and the government in the Sunshine Act. Attendance during the closed portion of the meeting will be limited to the NRC staff and its consultants, applicants, and those individuals or organizations who have entered into an appropriate confidentiality agreement.

We will confirm that only eligible individuals are in the close portion of the meeting. I would expect the closed portion of the meeting to be after lunch today. The subcommittee will gather information, analyze relevant information and facts, and correlate and propose conclusions and recommendations as appropriate for deliberation by the full committee.

A transcript of this meeting is being kept, and will be posted on our website. When addressing the subcommittee, the participant should first identify themselves, and speak with sufficient clarity and volume that they may be readily heard. If you are not speaking, please mute your computer on Teams, or by pressing star six if you are on the phone.

Please do not use the Teams chat feature to conduct sidebar discussions related to the presentation, rather limit use of the meeting chat function to report IT problems. For everyone in the room, please put all your electronic devices in silent mode, and mute your laptop microphone and speakers. In addition, please keep sidebar discussions in the room to a minimum, as the standing microphones are live.

For the presenters, if you haven't done this before, your table microphones are unidirectional, you don't need to speak into the front of the microphone to be heard. We'll probably coach you through that as the meeting progresses. Finally, if you have any feedback for the ACRS about today's meeting, we encourage you to fill out the public meeting feedback form on NRC's website.

With that I would like to turn over the presentation to the NRC staff, which will be Josh Borromeo, branch chief of Advanced Reactor Licensing Branch One, Nuclear Reactor Regulations.

MR. BORROMEO: Thank you, good morning. My name is Josh Borromeo, and I'm the chief of the Advanced Reactor Licensing Branch. As member Roberts described the purpose of today's subcommittee meetings are to discuss two topic reports, TerraPower stability methodology, and design basis accident, or DBA methodology for in vessel events without radiological release topical reports.

Both topical reports are used and referenced in the construction permit application for the Natrium reactor design for Kemmerer Power Station Unit One. TerraPower's overall licensing approach for the Natrium design will be the first application that follows the Licensing Modernization Project, or LMP methodology.

The stability methodology topical report provides a description of the method developed to characterize the Natrium sodium cooled fast reactor stability. The topical report describes the calculations and associated uncertainty treatment, as well as benchmark calculations using historical reactor measurements that were utilized in the model development.

The DBA without release topical report provides an overview and description of the model developed to evaluate in vessel DBA events for the Natrium reactor. The report summarizes the approach taken to satisfy the guidance outlined in Reg Guide 1.203 Evaluation Model Development and Assessment Process for in Vessel DBA Events without Radiological Release in a Natrium Reactor.

I would like to thank both the staff and TerraPower for their efforts in development and preparation of the material for the ACRS subcommittee meetings today and tomorrow. I would also like to express the staff's appreciation to ACRS for their time, and scheduling these two topical reports on the same day today, and the two scheduled for tomorrow.

Funneling these topical reports together creates efficiencies for the NRC staff. We look forward to working with the ACRS to find additional opportunities where we can find efficiencies, especially as we get into the construction permit review. We look forward to the conversation today, and if there are no questions for me I'll go ahead and turn it over to TerraPower, thank you.

CHAIR ROBERTS: Thank you, Josh. We have the slides up for the DBA methodology topical report, so TerraPower, go ahead.

MR. SCHULTZ: Okay, good morning everyone. My name is Richard Schultz, I'm a contractor with TerraPower. I have been working with them on especially adherence to MDOT, and the procedure methodologies for addressing design basis accidents, and specifically the in vessel without radiological release. I have a long history of working for Idaho

National Lab, I retired there in 2014.

I am presently teaching at Idaho State University. To that, I'll launch into --

CHAIR ROBERTS: Richard, let me interrupt you for a second, these microphones, you've got to be really close to your mouth to be able to be heard.

MR. SCHULTZ: Okay, is this better?

CHAIR ROBERTS: Much.

MR. SCHULTZ: So, with that I'll move into our discussion on this particular, our methodology shown on the slide. So, ready to move the second slide, whoever has control on the slides. Thank you. Okay, so the proper way to summarize this presentation, it's a presentation that shows that we're following Regulatory Guide 1.203, and we're adhering to it, and so this is a discussion of how we're doing that.

We've finished some of it, but not all of it. So, our objectives today are to give you a summary of that, and how are the scenarios treated, how when the reactor shuts down and the fuel cladding remains intact. So, the current topical report was written with the intention of supporting the preliminary safety analysis report, the SAR, as part of the construction permit application.

So, development is continuing as we continue to complete all the steps in the MDOT process, the evaluation model development and assessment process to support the final safety analysis report as part of the operating license application. Next slide please. The contents of this report is the definition of the different event parameters that are included in the scope of this methodology.

And the second bullet on this slide basically lists the four elements that make up the MDOT. So, the first is the requirements for the evaluation model development, two is the development of the assessment base, the third is the evaluation model development itself, the fourth is the assessment of the evaluation model adequacy.

The third topic addressed is the adequacy decision, and that will have conclusions and limitations. Next slide please. This slide gives an overall picture of where the in vessel DBAs without radiological release fits. So, were all quantified events, radiation source, so you see on the left we have captured the in vessel events in the red box on the right, and a green box for the ex vessel events.

So, the DBA methodology that we're

discussing today rests in the purple box on the left for the in vessel events. The tool we're talking about using, the evaluation model is SAS, which officially is known as SAS4A, or SAS1, and the fuel performance models that they have in that. We'll be looking at the figures of merit, we've shown the cladding temperature, the center line temperature, the fuel, and time at temperature no failure, TATNF, which is a methodology.

So, for our scenarios of course we had no clad failure, so we move into the events with release box and considering if that had anything to do with the events, that's still ex vessel scenarios. Next slide please.

CHAIR ROBERTS: And Richard I'll interrupt you if that's fine.

MR. SCHULTZ: Sure.

CHAIR ROBERTS: So, just one clarification and question. The clarification is the topical report we're discussing is just the first box in the left hand here, right? Okay, so three would be the topical report on the -- that's with release and ex vessel events, which we'll be reviewing in conjunction with the construction permit application probably sometime late fall, probably next year.

Can you talk briefly about how these four boxes, or this picture relates to the licensing basis event selection criteria? Because it would seem like you've got the AOOs, you've got the design basis events, beyond design basis events, and it would seem like this topical report is matched to more than just AOOs, is that right? Because clearly it does map to AOOs, right?

Because they have the requirements that seem to map to the criteria you have in that first box. But if you had an event that was a design basis event that did not have a release, would you also use that first, this topical report to evaluate it, or would you jump to some other criteria as -- yeah, definition of success.

MR. SCHULTZ: Well, those areas where you have a radiological release would be treated by other topical reports.

CHAIR ROBERTS: I'm thinking about things that screen as DBEs, or beyond design basis events where you don't expect a radiological release, would you use this topical report to assess them, and then if you're successful you'd stop, or do you start with the release methodology because your criteria would allow it?

MR. SCHULTZ: We discuss that a little bit more further in our presentation, but basically we start out with design basis events as defined by the NEI 18-04 report. And then within that group we just address the design basis accidents that put us in that box on the left.

CHAIR ROBERTS: All right, I was wondering if it was your goal to use this methodology for design basis accidents.

MR. SCHULTZ: Well, the first part of it for sure, okay? The -- until you actually would have a clad failure release of radiological events, then methodology applies. Once you get to that point then you will be in the box identified as events of release, and that would be additional modeling and procedures that we follow.

CHAIR ROBERTS: Okay, I think that answers my question. So, for a DBA if you were successful with this methodology you would stop, but then you would transition to the other methodology if you were not successful?

MR. SCHULTZ: That's right, exactly.

CHAIR ROBERTS: Okay, thank you.

MEMBER MARTIN: I'm going to continue on, this is Bob Martin. So, I was going to jump in on the next slide, because that's when they mention NEI 18-04. Can you move onto the next slide please? And one of the points Tom was making relates to the events themselves. Typically if you're going to leverage NEI 18-04, we'll see a topical report on th licensing basis event selection, and that methodology.

That would ultimately feed your design basis accident analysis at this because a portion of it forms the selection process. I guess we're not going to hear anything really about that. You're still going to be -- or are we, about the status of that exercise, and --

MR. SCHULTZ: No, that would be covered in --

MEMBER MARTIN: In -- that's not expected to really be necessary for the PSAR and CPA, is that -- well, it's kind of a licensing question.

MR. SCHULTZ: I think the methodology we followed when we go from taking it from a design basis event to a design basis accident we discussed, I think that would be part of the SAR. So, once you have a logic path, but this first topical report was just aimed at this one portion, this envelope, it'll have to be covered. I'm not exactly sure what the schedule is for covering that methodology, and logic, and so on.

But you know the adherence was to the methodology given in NEI 18-04, so it adhered to that as well.

MEMBER MARTIN: So you -- okay.

MR. KELLENBERGER: My name is Nick Kellinberger, I'm a senior licensing manager at TerraPower. So, the LBE selection process is following 18-04 without a deviation, so we do not have a topical report for that. We treat that and discuss it in the CP. This methodology takes the design basis accidents from the DBE region and does the first cut of in vessel, like you said, up until we determine whether or not there's fuel failure.

But for LBE selection, that's part of the construction permit application.

MEMBER MARTIN: I guess I didn't quite follow that. I mean, a couple points that are acknowledged in the topical report is that you're applying a conservative methodology, a deterministic methodology, which doesn't necessarily require NEI 18-04. Yet you use the language in NEI 18-04, and risk informing the process, it's a little confusing, and then you say you're not going to provide a topical report on the methodology.

Is it risk informed, or is it kind of more the traditional say how PRISM was licensed 30 years ago?

MR. KELLENBERGER: So, this methodology is deterministic, the selection of events is following NEI 1804, so that portion would be risk informed. So, you get that step that's in the DBE region, the design basis event region, and then you apply this methodology.

MEMBER MARTIN: But you're saying we're not going to see the topical report, there's not going to be a topical report.

MR. KELLENBERGER: That's correct, because we're following the approved reg guide without doing anything unique.

MEMBER MARTIN: The reg guide is a guide, right? You're going to implement the guidance, and what we normally see, normally expect is that that gets translated into your design specific application, that guidance. And of course you have, again, a unique design, sodium fast reactor, and you're going to get events that are different than other designs.

Consequently it's going to give you a different answer than say if this was a gas reactor. So, that seems to be a deviation from at least expectations. Now, granted, if this is a true Part 50 deterministic methodology, and there is some precedent for sodium cooled reactors, you could come in and just claim we're taking a maximum hypothetical accident approach, and maybe kind of bypass. But it seems like you're kind of blending functions.

MR. ANZALONE: If I may, Dr. Martin, this is Reed Anzalone from the staff. I just want to clarify that NEI 18-04 requires you to do a deterministic design basis accident analysis. I just wanted to make sure you -

(Simultaneous speaking.)

CHAIR ROBERTS: Closer to your mic, sorry.

MEMBER MARTIN: Right, but like I said, you don't have to go in and claim you're following this approach under Part 50, you can go down like I said, a maximum hypothetical accident, and others have done it, it's just a little confusing not to see the LBE and the selection methodology as it applies to Natrium prior to seeing this presentation on design basis.

Because you do that exercise, you identify where you have the minimum margins on these sort of things, you apply of course your insights from PRA, your single failure assumptions and other deterministic assumptions that ultimately define DBAs by that approach.

MR. ANZALONE: So, I do think they'll find that that is all done as part of the construction permit application, so yes, you're not seeing it right now, but you will see it when we go through that. This is just outlining the methodology that they're intending to use for the design basis accidents, and that we'll see as we review the construction permit application what the results of the LBE selection and identification process, how they get those DBEs and how those turn into the DBAs.

But the DBAs that they've chosen here, and I assume they're going to talk about this in a little bit, sort of encompass the limiting kinds of in vessel events that we would expect to see. And then there are lots of ex vessel events too that are important that we're going to talk about a little bit tomorrow, and as time goes on.

MEMBER MARTIN: Okay, so you're saying it's basically articulated in the construction permit application, I mean are there accompanying say technical reports that first we would normally see that support this?

MR. ANZALONE: I would say that we've seen a bunch of it in audit space, but also I think a lot of it is just in the construction permit.

MEMBER MARTIN: So, we'll see it at a later date basically, all right, thanks.

CHAIR ROBERTS: Part of my confusion, the reason I asked the question on the previous slide is the term DBA, and the title of this slide, the DBA is a very specific term in LMP space, which is a deterministic conservative construction of a design basis event. You've got to anticipate operation occurrences, you've got design basis events, you've got beyond design basis events, and you've got events that are screening by cliff edge effect determination.

And I'm a little unclear how that interrelates with this topical report, and I think what you said earlier is that AOOs would use this topical report, even though AOOs aren't DBAs, but AOOs have requirements that are consistent with the construct of this topical report. You're not allowed to have a release from fuel is typically what an AOO is required to support.

So, it seems like this methodology is intended for AOOs. What you said earlier is it's kind of a screening methodology for DBAs, that if you pass, great, if not, you go to the next step, and I think I understand that. And I assume DBEs and BDBEs will be in a similar category, that if you passed on this methodology, great, if not, you go to the next methodology. Is that all right?

When I read through the CPA chapter, I didn't quite get that out of it, if that's what you were doing, that's what I wanted to clarify today.

MR. ANZALONE: So, I can probably contextualize that for the construction permit application. Sorry, again, this is Reed Anzalone. So, the CPA says that for DBAs they use this methodology specifically. They say for the AOOs and DBEs, and BDBEs that they use a similar methodology. But because they're not DBAs with that baked in stylized conservatism that's part of the DBAs, they use what they say is a similar methodology that I think is basically the same codes, but without that conservatism applied necessarily.

But, I mean it could be applied in certain cases as well depending on how they want to analyze it.

CHAIR ROBERTS: Sounds like a discussion when we get to the CP application, thanks.

MR. SCHULTZ: So, I'll continue?

MEMBER MARTIN: Well, give me a second,

Member Martin again. So, in the title we have without radiological releases, but we know that the fuel of Natrium is not like LWR fuels, it's not much of a barrier, right? So, these events could at least move fission products into the sodium and elevate the concentration, or the activity in the pool itself.

Do the results from these DBAs then say inform the sizing of your clean up system if you -- because obviously from these events you're just going to recover, the intent is to recover, and you of course have to deal with the increased activity of the pool. How does that come into play?

MR. SCHULTZ: Well, as I recall NEI 18-04, the way that you define an event in terms of the radiological release for example will define how you characterize your system, how you define your system, how you specify your system. So, I think the answer, I think you asked a question about does it effect that, and the answer is yes.

MEMBER MARTIN: And there is still source term analyses that are done, right? And there are exposures, it's just not for events like this, you have no off site release. You're still going to have to be concerned about facility workers and such. So, it's not without radiological release, it's just not without any kind of off site type shifts there, and you do have to acknowledge that you don't quite -- you have a different fuel system than others, there is some cleanup that has to be done.

Of course they have to be sized to accommodate, and I assume you would have some radiological analysis for that, yes, I see a nod over there, okay, all right. And will we hear about that?

MR. LUO: That will not be part of the in vessel DBA without release, because that's a higher release that we'll cover in the in vessel DBA with release methodology.

CHAIR ROBERTS: And I'm sorry, can you identify yourself for the court reporter?

MR. LUO: Hugh Luo from TerraPower.

MEMBER MARTIN: And there's only three mics over there, so you might have to be sensitive to that. So, anyway, just keep that in mind as you go forward. Okay.

MR. SCHULTZ: Okay, so in treating this we looked at what would be called representative in vessel design basis accidents, and we identified the loss of offsite power, the loss of heat sink, and the rod withdrawal at power as similar, they'd be representative. We then made a composite, we did parts for all of these scenarios, and we then created a composite part, which identified the highly ranked phenomenon, the medium ranked phenomenon, for example, to be able to look at.

And two, our assessment matrix, which you find in element two to these scenarios. So, these are the three scenarios that we worked with. Next slide please. So, this is the first slide that actually embarks on the discussion and content of EMDAP, and so we follow the guidance given in Reg Guide 1.203 together with NUREG-1737, which is basically a report from the NRC deals with quality assurance, software quality assurance procedures of the NRC and all codes to achieve compliance with reg guide position one.

Now, reg guide position one, which is given in Reg Guide 1.203, is basically the flow chart which is identified on page six of EMDAP, talks about the formula that you should follow, and which, which should be, slide three. So, the first element, element one, deals with the evaluation model capability requirements. So, this is the element where you define the system, you define the components of the system, you try to identify the physics, and find out the whole thing is a phenomena identification and ranking table.

So, it's comprised of four steps, and that then is the means of defining the envelope that you're going to require your licensing model be able to evaluate. And also we identified the hierarchy of the different phenomena in terms of high rank, medium rank, and low rank, and the different physics that take place in the various components that make up the system.

The step one is the analysis purpose, and basically this is where you're setting the stage. So, ensure your plant operations are in compliance with the general design criteria under the normal operating conditions, and during an in vessel DBA without radiological release next slide please. Moving through the following steps in element one, the step two is to define figures of merit.

There's a bunch of those listed there, temperature coolant, time at temperature for the cladding. We broke down the system of Natrium into its systems, components, phases, geometries, and so on as identified in the topical report, and we showed our approach following guidance given in NUREG/CR-6944. That is the NGNP part of the document, generation nuclear plant.

This is an example that's done by the NRC for the next generation of nuclear plant. And as it states in that bullet beneath step four, it's b to h here, composite part combining conservatively the five individual parts that were individually performed as three scenarios.

MEMBER MARTIN: This is Bob Martin. So, did you just pick up the part from the NUREG, or?

MR. SCHULTZ: No, we wrote the methodology.

MEMBER MARTIN: So, but that was your baseline, and then you looked at maybe deltas, and design specific deltas from that, or?

MR. SCHULTZ: I missed your question, could you -- okay, go ahead.

MR. LUO: This is Hugh Luo from TerraPower. So, we follow the NGNP per the process, how they identify phenomena, ranking of phenomena, and also for the importance, and the non-leaking ranking. For the Natrium PIRT, that's not devised for the NGNP PIRT. So, NGNP PIRT, while most folks think the high temperature gas reactor design is not for the Natrium design.

So, we did have other reference, for example the PIRT done by NRC, also like a total ship out for this PIRT done in Japan. So, we do have other references we start with, we're not getting everything from scratch. But we do independently identify the phenomena during the PIRT panel evaluation, and compound the PIRT branching.

MEMBER MARTIN: Okay, all right, thank you. Normally I wouldn't reference NUREG-6944 as the process. The process, of course Dick knows well, goes back to a number of Idaho documents, EG&G documents like Gary Wilson and just NUREG-249.

MR. SCHULTZ: I think it was specifically brought up because it was something done in conjunction -

CHAIR ROBERTS: We can't hear you.

MEMBER MARTIN: Richard, can you speak up please?

MR. SCHULTZ: Yes, okay, sorry, I tend to mumble.

CHAIR ROBERTS: We'll help you.

MR. SCHULTZ: Any other questions on this slide? Okay, we'll move forward to the next -

MEMBER PETTI: Yeah, this is Dave Petti. Fuel centerline temperature, that tends to be the maximum temperature, as opposed to just saying maximum temperature as a criteria?

MR. SCHULTZ: Yes.

MEMBER PETTI: That's the location of the maximum temperature in almost all the transients?

MR. SCHULTZ: Yes.

MEMBER PETTI: So, it means the same thing, just -- okay.

MR. SCHULTZ: Okay, next slide please. Okay, here we move into discussion on element two, and this element specifically deals with the development of the assessment database, and the assessment matrix that you use to form your adequacy calculations on the evaluation model. So, here we're dealing with looking at what's available in terms of vintage data from legacy experiments.

And then ensuring that we define new experiments that capture the specific characteristics of Natrium, and that are applicable to the highly ranked phenomena that are of interest from the PIRT -- that have been identified in the PIRT. So, step five, first step within element two, is assessment base objectives. And here is where we look at the spectrum of facilities that would be required to supplement what's available in the legacy experiments to ensure we have sufficient experimental data. Next slide please.

MEMBER PETTI: Dick?

MR. SCHULTZ: Yes.

MEMBER PETTI: So, as I read this, it sounded very thermal hydraulic. I don't want this to sound wrong, but I think we all know sodium is a damn good coolant. And what I didn't see is a lot of discussion on physics. The reactivity coefficients, and how methodology is going to help transients in which there is feedback, and how well do we know that, what are the uncertainties?

Again, I don't see any experiments, this would have to become the operating experiment, but I was expecting to see a lot more about that, and a lot less about thermal hydraulics, because sodium is a good coolant, I think we all know. Go back and look at PRISM, and look at what NRC paid Brookhaven to do, compare it to GE 1990s, it looked really good for 1990s code. So, is there another topical that's going to talk about the physics side specifically? So, it's just sitting somewhere else?

MR. LUO: Hugh Luo from TerraPower. Yes, those we'll be covering in the core design methodology, so outside of this in vessel DBA.

MEMBER PETTI: Okay, that helps a lot. Feel for us, we only see little pieces of the elephant, we're trying to see how all the pieces fit together. Thank you.

MEMBER MARTIN: This is Member Martin, and I know your presentation is pretty terse, I'm going to jump in here with kind of a related comment. Maybe not so much to physics, but one thing that I couldn't help but notice was of course your choice of the code and its own limitations, as it's a pretty old code. It's a systems code, 1D code, and this is 2025, and it seems to be pretty inconsistent with the way the trends have been for quite some time.

Of course, Dick, I don't know how many presentations I listened to you on use of CFD and licensing, and it just seems a little ironic for you to be coming up here with a code that is anything but some of the things that you've advocated for in the public domain. Why? And I wondered, and I bring it up now because I wondered if in some way it biases your PIRT.

Because there's some asymmetry of flow, flow distribution that is mentioned, but those begin to lead to the question of are you at any higher fidelity in the core, subchannel bottles, multi-D models, that sort of thing. And I felt like that was a little weak. But then I have to think well, this tool has been used to license a reactor before, and using the old methods.

What led to these kind of decisions to kind of go and use the path that had been -- you tried it before, as opposed to following what everyone else seems to be doing nowadays, and seeking higher fidelity? At the same time it's still important to acknowledge the high fidelity, the real physics that's going on, and some of it is going to be multi-D that's going to be outside the capability of SAS.

Do you want to comment on those choices, and my concern was really did it in someway bias the PIRT process, given the limitations of the code itself to 1D.

MR. LUO: This is Hugh Luo from TerraPower. So, we do appreciate Dr. Martin's insights on the SAS code, and in TerraPower we do annual indexes evaluation to the SAS code, evaluate the model that has been using the code, the thermal hydraulic and the numeric scheme using the code, and we also identify certain limitations with the code.

We did work with the code developer, which is Argonne National Lab, trying to improve the code not only for the model, but the process the code has been using. So, we did perform the commercial grade dedication to this site's code to promote the quality level to meeting the safety analysis requirement.

So, we have found the process, we did identify a single limitation as Dr. Martin referred to, and we will refer to the detailed discussion on those properly in the closed session.

MEMBER MARTIN: Okay, there's only five minutes allotted in the closed session, so I was going to get my darts out there, but we can do whatever you want in the closed session of course. Okay.

MEMBER PETTI: But also I thought I read that you are doing some CFD to inform the mixing and planar striping all the old issues that have been around a long time for all high temperature systems. So, it's not like you're not using CFD, it's in the background, which isn't very, I guess typical of those systems, I guess you could say.

MR. LUO: This is Hugh Luo from TerraPower. Yes, we did mention use of safety in the Natrium evaluation. The safety code does have much higher fidelity than the SAS code evaluation here, and especially for the region that houses three dimensional phenomena that 1D model cannot be able to accentuate those details.

So, again, we do have that discussion with

NRC staff, the safety code will be used to provide additional insights to the safety analysis, but will not be the safety analysis evaluation model itself.

MEMBER MARTIN: I guess you were right.

MR. SCHULTZ: Okay, any further questions on this slide? Let's move on to slide nine I believe. This slide we embark on the discussion of remaining steps that make up element two --

CHAIR ROBERTS: Dick, a little closer.

MR. SCHULTZ: Sorry about that. Here's where we embark on our discussion of the remaining steps within element two. So, of course for the design of experiments that we have to build facilities that -- and even for legacy data that would be used directly for any particular phenomena in the Natrium reactor with component scaling analysis and similarity criteria analyses, and we're doing that using the H2TS process, the hierarchical two tiered scaling methodology for our closed coursed and natural circulation flow loop.

Step seven is the development of the assessment matrix itself, and so it'll be comprised of both legacy test data, as well as data from the experiments that we build. Moving into step eight, which basically we're still defining those facilities.

Basically this is work that needs to be performed, so this is the evaluation of the distortions, and the scale up capability of the separate effects tests that we'll use. So, that's work to be performed.

And of course step nine, the experimental uncertainty determination. All right --

MEMBER MARTIN: I'll jump in here again, this is Bob. So, of course I saw the list of, I guess it would fall into the category of legacy tests, and integral and separate effects tests. What would have been nice to see would be kind of that mapping -- I mean I guess it's there a little bit in the narrative, but a mapping of phenomena, like in a table of here are the test facilities.

And then we've all seen the tables that will have the phenomena kind of in columns, and then the check boxes against all the different test facilities, that sort of makes it very easy to see the coverage. Invariably there's gaps, right? You did your PIRT, you identified gaps, and then you have to go off and do these other tests.

Can you kind of quickly just kind of talk about the gaps from the test databases, of what you have access to. I mean, there's tests out there you just don't have access to, I certainly understand that, that you have to go off and just kind of own, sort of take over the responsibility to do those tests maybe again, but by the phenomena, and maybe some of the testing that you are doing.

MR. SCHULTZ: Yeah, I think there's -- the table, we probably need to expand it in terms of weights in it, I suppose. But I know it does show the phenomena that we're identifying, I think. But you're right, determining the kinds of data, and the correspondence between fore example the separate effects legacy data that's available, versus the Natrium design geometry of it and so on, that is what we're still working on.

Clearly not all of the legacy data works like Natrium, and so there's gaps, okay? And so, we're basically identifying exactly what that -- translating what that means in terms of facilities that we'll need to actually design and build.

MEMBER MARTIN: So, one thing I also noticed in reviewing your PIRT as a decision making tool was that you emphasized the importance metric, but other than acknowledging the state of knowledge, you didn't really incorporate that, I think into the decision making process. And I do know that Eric Williams of course it's everyone's boss, and he was involved with the PIRT that I was involved with Gary Wilson.

Of course I considered Gary the father of PIRT, to put a name name to the place, and Gary maybe his thoughts evolved, but certainly by 15 plus years ago he came up with this idea of risk perspectives, which is a combination, is a metric, a simple metric that combines importance with the state of knowledge.

Such that high importance with low state of knowledge just percolates to the top, where you end up having that emphasis. And certainly nothing you can do about it now, but I would highly recommend that you consider this risk perspective to help kind of filter the priority. Instead of just subsequent to that PIRT, and identifying high importance, because certainly to me, and I guess you did say this.

High importance with high state of knowledge, for the most part those are kind of boundary conditions they've used, that's fine. But then the emphasis on only high after that without an acknowledgment of the state of knowledge seems to potentially miss certain risks. Now, when I was looking at this I didn't see very many phenomena identified as low state of knowledge, which actually bothered me too.

Because if everything is high and medium, it's not such a useful metric anymore. Remember once upon a time with PIRTs, we had a ranking from one to nine, right? And it was like double that, and we kind of relaxed that, but relaxing to three is probably the limit. If you only have highs and mediums, I'm not sure how useful that is.

So, another thing if you ever revisit the PIRT is scrutinize that a little bit more, and allow for a finer assessment of these phenomena relative to each other. But --

MR. SCHULTZ: Yeah, there were a low number of phenomena that had a low state of knowledge.

MEMBER MARTIN: Yeah, and I mean sodium is not new, but there's just not as many people that are experienced with it, for sure. And you have a new generation of engineers being involved, which is not quite the same thing as a low state of knowledge, but you don't necessarily have access to the raw knowledge sort of thing.

So, state of knowledge is also a function of what you really have access to. It's not just what somebody once upon a time knew. But keep that in mind because somebody is looking at.

MR. SCHULTZ: Good point. And this is an

iterative process, our approach is iterative.

MEMBER MARTIN: Of course, absolutely.

MR. SCHULTZ: This is part of the process and we're moving forward down the path I think that you're poking.

MEMBER MARTIN: So, you do plan to kind of revisit this in some sort of formal sense?

MR. SCHULTZ: Yes, that's right.

MEMBER MARTIN: All right, that's good to hear.

MR. LUO: This is Hugh Luo from TerraPower. So, firstly on the risk informed decisions on the PIRT, we do increase the amount of sensitivity calculation using certain quantification processes to hereby confirm the ranking that the PIRT panel made in the PIRT. So, that process we've highlighted before, and we are increasing the representative sensitivity calculation to confirm the PIRT as the design is more mature in Natrium design.

So, the second part is on the high importance rank, there's not many phenomena ranking at low and this partially reflects the specificity done has been historically developing in this country and around the world, it's one of the most mature advanced reactor designs. So, fundamentally for the phenomena, I think in the community have really good understandings on the phenomena in the SAR.

The challenge, or the gap with high visibility on the Natrium specific geometry space safety design, for those areas that our knowledge is not sufficient, but we do plan additional space safety testing, mapping Natrium design, Natrium geometry, trying to have a better understanding of those phenomena.

MEMBER MARTIN: I appreciate that, thanks.

MR. SCHULTZ: Okay, so any further discussion on these steps? Let's move to the next slide, please. Okay, this slide has a discussion on element three. Element three is the evaluation model development. And so, beginning with step ten, that basically identifies a developmental plan, which is based on following the procedures and standards that are given in regulatory positions two and three of Reg Guide 1.203.

So, reg position two has to do with the QA requirements, the quality assurance requirements. So, we're following reg one. Reg position three has to do with the documentation, so having adequate documentation about the evaluation model, all the appropriate values describing the fuel relations, the closure relationships, user guide and so on.

So, the EM structure is going to be SAS4A, SASSYS-1, which I'm calling SAS. That's the model. So, using QA guidelines, procedures followed, follows the documentation for SAS. In terms of the closure models and conservatisms, in step 12 there's three new closure correlations that have been implemented in SAS.

Also inserting conservative biases on normal inputs, and using conservative model assumptions together with model options. And for these scenarios, we'll just be using safety related structured systems in common as required.

MEMBER MARTIN: This is Bob again.

MR. SCHULTZ: Sure.

MEMBER MARTIN: Light water reactors of course have the benefit of Appendix K, but people a long time ago sat down and decided what deterministic safety analysis methodology looked like for light water reactors. That doesn't really exist for sodium fast reactors. I believe PRISM was licensed that way, so there has been some thinking on that.

Are you -- I mean bringing in that experience from PRISM in particular, and doing that? I guess even EBR2 would have had to be licensed under a DOE framework. What are the precedences that are driving this, or is the intent to leverage the knowledge that you have related to the previous steps on testing and uncertainty analysis, and using that to ultimately set conservatisms in your methodology?

MR. SCHULTZ: Well, we're working within the framework that was established by the work done on PRISM. But then using specifically the systems, using the framework and working in that context, and just using the specifics that are characteristic of Natrium.

MEMBER MARTIN: So, for process uncertainties, that should be fairly straightforward. Phenomenalogical uncertainties are obviously really the hard ones there, now your response to my previous question just doesn't seem to really answer that. That's why I asked well, okay, there must be precedence on at least he phenomenalogical items.

Throw in the relatively simple modeling that SAS provides, again, I can think of Tong and Weisman, and what they first did with simple models with light water reactors and hot channel factors, that sort of stuff, and all that was fine. But again, they were able to work under an Appendix K environment with more of an established consensus on what's important, and what are the appropriate uncertainties that are treated.

You own that, and what are you doing to build up your arguments that its conservatisms are appropriate and adequate? So, that's why I'm trying to lead the witness and say well okay, what do you know from PRISM? I mean, can you leverage that? If you go off and then do your own testing, and do with uncertainties, are you just going to stack those uncertainties?

I personally feel like if I was doing this, I would be doing a lot of sensitivity studies, and all this sort of stuff. And clearly the ones that show relatively little sensitivity, I might just go nominal and have a justification for those nominals, those do show greater sensitivity to your figure's bearing, I will stack those. But I want to hear that from you, as opposed to guessing what you're doing.

MR. SCHULTZ: That is what we're doing. Hugh?

MR. LUO: This is Hugh Luo from TerraPower. As for the uncertainty, we do recognize the agents who are far away, we do not have as much experiment, as much proportional data that can support us to give a really conservative value on uncertainty.

So, what we start with is taking a much wider uncertainty range, and use that performance and sensitivity calculation to confirm the impact purely based on merit.

That does feel important, and we do not have much experience kind of in those lines, or confirm the value of the uncertainty, or the distribution of uncertainty. So, we typically take a much wider range on the conservative side, and our humor slide distribution, or the normal distribution that we believe are conservative.

So, that's basically we're starting with quite conservative on the uncertainty. And as the process is moving on, and matures, we are trying to include that uncertainty, we are either doing more investigation, or doing more experiments trying to see how and if we can narrow down this branch, and give a better description of the uncertainty.

As for the source of uncertainty, like phenomena uncertainty, they think that's very important, and that has to be an industry experiment, or we're doing sensitivity type relation to getting further, a better understanding. And then we also did perform the PIRT, for the high importance phenomena in the PIRT we do make sure we stress those phenomena in the uncertainty, in the values.

And also from user input, for the engineer working on the evaluation model on the methodology. They have a good bearing on what parameter might be important. So, we do performance sensitivity calculation to confirm those parameters are important or not.

MEMBER MARTIN: And to your last point, did you have to modify the code to introduce new parameters to say effect sensitivity on phenomena that you identified in your PIRT? Again, I'm thinking SAS is old code, it's only been used in a deterministic sense, but to do those kind of sensitivity studies you may need to have additional access to the models through code input to be able to do that.

MR. LUO: Yes, SAS code does give you the choice to change the parameter, and for the specific relation that believe is important, and we need to have a better handle on that. We do work with Argonne trying to improve the code, give us additional choices on those parameters that we can do the sensitivity calculation.

But I'm not trying to say that we're doing a whole lot for that. Though that's most of the relations that we believe improvements are needed.

MEMBER MARTIN: Okay, and you acknowledged that earlier a couple slides back. Thank you.

MR. SCHULTZ: Okay, we'll move to the next slide please. Okay, this slide is the beginning of our discussion on element four of EMDAP, which is the evaluation of the model adequacy assessment. And basically element four consists of two parts, the bottom up evaluation, the evaluation of closure relationships, which are steps 13 through 15, and the evaluation of the top down evaluation model, which will be steps 16 through 19.

So, these steps, accomplished by looking at the pedigree, and fidelity, and scalability, achieve compliance with principle four, okay. Principle four is basically to assess the adequacy of the evaluation model which is identified on page four in Reg Guide 1.203. So, the first part, this is all to be performed, so steps 13 through 15, this is looking at the closure relationships.

And with respect to the characteristics I just mentioned, the pedigree, applicability, fidelity, accuracy, and then finally scalability of the models scaling up from the separate effects tests facility data to the full sized, full scale Natrium. And then of course, the integrated evaluation model top down is made up of steps 16 through 19, and fundamentally is the same overall approach that you would use for closure relationships.

You determine the capabilities of the fuel equations and granular solutions, assess the system interactions, and global capabilities. So, just looking at the interactions between components and the interactions between the physics that are characteristic then of each of those components.

And only the scalability then of the integrated calculations in the data for distortions. The final step is step 20, which is to determine the biases and the uncertainties of the evaluation model.

MEMBER MARTIN: This is Bob again. Regarding the verification activity, which I think gets captured in the top down evaluation of the EM, I picked on you for SAS and its lower fidelity relative to 2025 codes. You did mention you have some CFD that you are working, is the intent, this corroborative evidence to show that when you incorporate higher fidelity physics SAS is still kind of given reasonable type understandable first principles kind of answers there?

And you say CFD, what does that mean, what code are you talking about in that sense, use it, I know Argonne also is SAM, SAM can deal with sodium right? Are you using SAM, or are you using -- I think RELAP can do some of this, obviously go to STAR, you know.

MR. LUO: Well, safety specific, in TerraPower we are using STAR-CCM plus plus so --.

MEMBER MARTIN: Okay, CCM, okay. Anything in between as far as relative?

MR. LUO: We do have relevant code of other -- another kind of code we are using, but it is trying to suppose using transient analysis, so it's not for safety analysis.

MEMBER MARTIN: Okay. Again, the advantage of course using these tools, you really don't necessarily have to have the same QA level, because you're seeking that corroborative or qualitative evidence that you have. Your manuals should be showing more or less the same field equations, and similar if not exactly the same closure relations, that as long as they're kind of consistent with each other, it's really the only value of code to code comparisons, is in the verification space.

And I think over the years depending on who was in the room, code to code comparisons were dismissed as being valuable, but they're certainly not appropriate, or not a surrogate for validation, but they are appropriate for verification. And it sounds like you do have those tools, and you are indeed leveraging them to support your safety.

MR. SCHULTZ: It'd be for a classical V&V process. Okay, next slide please. So, the adequacy decision. This basically will be following the process of using metrics and the standard questions that relate to the adequacy of the tool to satisfy the requirements of this process, and specifically for Reg Guide 1.203.

Of course to determine the adequacy you have to show that you have a satisfactory answer to all of the adequacy questions. So, all of this is to be performed. We will be adhering to the requirements that are established in the reg guide.

MEMBER HALNON: This is Greg. I'm not steeped enough for Bob here stuff, but I go through all of this stuff, and then I get to the end saying is this all okay? And it says we don't know yet, we're going to perform adequacy. Is that normal to the way these come out? Is that typically the way these evaluation models are inflated, is that you have to just get some time behind it, and some more, I guess experience.

Is that typically the way it goes? I was surprised, kind of at the end of it after all this reading, and cogitating in my head, it says well we're not sure if it's okay.

MR. SCHULTZ: Well, for example, for all of the important processes and phenomena we have to demonstrate the evaluation model can either have a reasonable --

MEMBER HALNON: So it's an evolutionary issue, you have to get some experience behind you running the model, does it make sense, does it --

MR. SCHULTZ: We have to build models of each and every one of the experiments, you have to consider the databases that have been made available from these different experiments, so we want to include it in our assessment matrix.

MEMBER HALNON: So, I shouldn't be alarmed by that last bullet then, you're saying that that's typical the way these work out.

MEMBER MARTIN: So, there are metrics that you determine along the way, obviously related to assessments and uncertainties that -- well, it's top down, bottom up, so you start out at the high levels and get down to the low levels. The uncertainties of the separate effects should be propagated into the uncertainty treatments in their analysis of record types of solutions.

MEMBER HALNON: As the design matures the model will.

MEMBER MARTIN: But the reg guide isn't going to say it's a given that you do all these things, it's done, you do have to check. And so I think that's really just an acknowledgment that they haven't quite gotten to that point yet because they haven't checked all the boxes.

MEMBER HALNON: There's a lot going on.

MEMBER MARTIN: There's a lot, yeah, a lot of work left to be done. So, it's certainly a reasonable way to conclude the presentation.

MR. SCHULTZ: Yeah, so we used a separate effects table for the closure relationships, and the overall behavior we use in that facility.

MEMBER PALMTAG: Yeah, this is Scott Palmtag. Just to follow up on what Greg and Bob were taking about though, you're not just starting out, I mean you've been working on this for a long time, and actually you're getting ready for your construction permit. I'm kind of surprised you haven't done validation verification on your codes, and run all these experimental data yet. I mean shouldn't this have already been done quite awhile ago?

MR. SCHULTZ: Well, one of the bases for selecting an evaluation model is the work that's already been done on it. So, you start at that point, so SAS has been used historically to perform calculations on the behavior of sodium fast reactors. So, that's the place you begin with. And then you have to determine that the models that are in it are applicable to all the physics that you encounter in natrium.

So, that's really the step up. You have to continue that that will inform you, and demonstrate that SAS is capable of calculating that behavior, and so that's the process that's ongoing at this point.

MEMBER PALMTAG: But you do have a design ready on it, you're very close to start building, and you have the EBR2 data, you have all the code, you have all their information, so have you run SAS with all the verification validation cases?

MR. SCHULTZ: We've run it for most of these -- like EBR2 for example, yeah, we've run SAS on that for sure.

MEMBER PALMTAG: Were you actually seeing any results, or is this more just the basic methodology of how you approached this?

MR. SCHULTZ: We're trying to outline just ensuring that we are following the reg guide, and being very specific to follow it as defined. EBR2 for example is a very old facility, it doesn't have a major amount of uncertainty associated with it, it has a lot of questions. So, yeah, we performed those kinds of calculations, but it is what it is, it's a 1960s facility. So, you can only go so far with that.

MR. LUO: This is Hugh Luo from TerraPower. So, on the verification and validation of the SAS code, for the verification part we basically conducted with Argonne on the process under the commercial grade dedication. We do have separate simple issues that cover simple equations, those who have been calculating the code concurrent with a solution.

That's fundamentally, and then we have kind of separate effect tests like IET, like EBR2, like Phenix FFTF all those kind of validation have been completed on their side. Those are also not only for TerraPower, but for the IAEA benchmark that's also the international community using the same comparison for validation for the code.

What TerraPower is focused on is really trying to scale up capability all over the validation.

The fundamental phenomena in the code helping validate, and helping using the community database and TerraPower's focus is really on identifying experiment uncertainty, which should correlate like in the IAEA benchmark, there has been lots of focus.

And also we are focusing on the scale up capability, the geometry difference, whether there's geometry difference in the IET, whether that will have impact on our Natrium design or not. So, basically we are focusing on a lot more fidelity of detail on the validation. So, there are enough ongoing validation researching that has been done for the code.

MEMBER PALMTAG: That's what I was looking for, this has been done, you have done the verification validation.

MR. LUO: I would not say we have done that, so that is still an ongoing process, but we do have some --

MEMBER PALMTAG: You have not turned on the reactor -

(Simultaneous speaking.)

MEMBER PALMTAG: -- before you do the verification validation and know if your codes are right, that's fine.

MR. LUO: Yes.

MEMBER PALMTAG: So, you have done the verification validation?

MR. LUO: We have not done the verification validation under NRC regulation requirements but there are other activities under verification validation of the SAS code has been done not specifically for the Natrium design, and there has been international benchmarks.

And also in TerraPower we also have done the EBR2 validation and FFTF validation, intermediate loop, nitric recirculation valve validation. For those four pairs we have done in TerraPower.

MEMBER PETTI: So, simply you do have confidence that you're going to pass here, you just haven't dotted every I and crossed every T.

MR. LUO: Yeah, that's correct. We do have additional new tests that do not have the data available yet, so we did not do everything on validation for the Natrium under requirements, we do have a lot of activity helping give us sufficient confidence of the code capabilities.

MEMBER PETTI: Let me just follow on from that. I was very surprised when I read it, that None of the historic experiments scaled properly, I mean that was eye opening to me. Because I mean, if we take 1.203 off the table, let's say it didn't exist in a different universe, you'd rely heavily on previous operating experience.

That's what we do, right? That's how we reactors have been built, and operated, and et cetera. Can you give us a simple sense of what is it that doesn't scale properly? Let's say FFTF and EBR2, how come they don't scale properly with Natrium? Simple without a lot of detail.

MR. LUO: This is Hugh Luo from TerraPower Again. So on the EBR2 the key difference is they have a way pipe came out from the core, goes through the pipe, and goes to a much smaller hot core. But in the Natrium design the hot sodium came out from the core, and enters the hot core. So, it's almost like taking, impact in the hot core will be different in Natrium and EBR2.

FFTF, FFTF are a dual loop design, so we are a core design, so we have to have a major difference there.

MEMBER PETTI: Okay, but in the core itself, they're scalable, I mean you're talking about stuff that I consider to be outside of the fission gate, the plenum of the loops. So, the core itself, any data we have there is good from EBR2 and FFTF, what they would tell us about Natrium.

MR. LUO: For the core region, if you talk about like with that physics, and with that coefficient, so those are outside this methodology, so I probably cannot provide more comments. But in order for validation in the cyclical analysis evaluation model, we do have data in those in codes from the core design methodology.

So, they will do their own verification validation for those input parameter to the safety analysis, and in the safety analysis evaluation model we do perform verification, and validate which of those parameters provided to us behave properly in our code, and combine them with permanent data.

MEMBER MARTIN: I was just going to kind of follow up at a high level. So, you've gotten good cooperation from DOE to get data, and maybe input models for SAS, and do you have these all in house ultimately to support 10 CFR 50 Appendix B quality application, quality V&V effort, do you have that in house?

And one of my motivations for asking that question, one of the reg guides, I think endorses EPRI's approach to V&V, or commercial rededication I should say, and they describe four methods. Method one is this historical experience, however that EPRI document, and of course by NRC endorsement of that document, acknowledges that is not sufficient approach.

You can't just say well let's pick on some random university, say MIT professor does a benchmark, and shows SAS does good results, that's nice, but it's not good enough, you're not doing that, right? You've brought this in house, you're not only dedicating the code, but you're dedicating the models, you've dedicated the data, you're doing all that, correct? That's ongoing?

MR. LUO: Hugh Luo from TerraPower. For the code we do separate commercial grade dedication following the EPRI guidance on that. And for the data, basically we are trying to make that data comply with TerraPower QA procedure, which again complies with N301 requirements. Not all the data, in fact as Dr. Martin mentioned, may be able meet the N301 requirement.

Because some of it has been done many decades ago, they did not perform under the N301 procedure and it's -- we will do the data quality evaluation and the data qualification process per the TerraPower QA procedure. And we do expect some of the data will be able to meet the N301 standard, and some of it may not be able to do that.

For those quality guides, so we will find that these are lot of test facilities that maybe can give us additional independent verification if this data is correct or not. So, for those quality guides we do try to compensate the data quality guide, and we recognize that not all the data can be N301 data.

MEMBER MARTIN: Okay, and that's a common challenge given all the work that was done say before 1980 in particular. But to my point, you had no problem bringing in the data and models from DOE, whether it's in EBR2, or Argonne, they've been cooperative, and you were able to actually --

MR. LUO: For the DOE data, we do collaborate with DOE trying to get the data, EBR2, FFTF, we are able to access those data. And for the data that's outside the U.S. typically it will be more challenging for us. TerraPower generally has to reach out to the data owner trying to negotiate each agreement to acquire the data. So, that is actually a different type from DOE.

MEMBER MARTIN: Right. And kind of to that point, EBR2 was a 50 megawatt thermal, correct? 62, okay, 62 megawatt thermal. And of course your design is 840? One unit, okay, so it's about a factor of eight, but regardless my point is it's a larger core, where a multi dimensional modeling might actually be required.

SAS, is that just point kinetics in this particular case? And so, do you have as a verification, capability to model a higher fidelity core, and at least to confirm the behavior for the scaled up design?

MR. LUO: Specific to the DB6 analysis in the SAS code they are still using the point kernel model, and we do perform additional evaluation comparing the point kernel model with the spatial time connected model outside of the SAS code trying to confirm the impact of the simplification using point kernel model.

So far that indication most came up on this specific event where you have control data with the load core assembly near the control data may have a different distribution than the point kernel model can handle. So, we'll provide additional calculation with higher fidelity to confirm the impact of that spatial connected model that may increase the local hot spot power.

And we will address those local hot power in the safety analysis, so those are the impacts will be addressed in the safety analysis, but not direct, with coupling with the high fidelity core model.

MEMBER MARTIN: Okay, and I want to channel our leader her, Walt, who is on vacation, Walt Kirchner. And one of his favorite questions relates to the fuel rod growth, right? And that certainly at power you get fuel expands, and contributes actually negative reactivity, and to some extent the plant relies on that negative reactivity.

What is being done to characterize that, and understand that, and get that back into your point kinetics model? Where does that knowledge come from, just physics analysis, or how are you characterizing that contribution to total reactivity?

MR. LUO: In the DBA safety analysis the reactivity inputs is coded, so under the basic value can tune the model to inform the code design. They do have a higher fidelity model which could be very fast in validating, and sort of confirming those values. And also those values came with necessary bias, conservatism, the power of the potential uncertainty.

So, once they are put back into our safety analysis tool, we do have separate verification and a validation to confirm we are properly incorporating those coefficients into the safety analysis.

MEMBER MARTIN: Look at Scott, do you want to jump on that and flesh it out?

MEMBER PALMTAG: Yes.

MEMBER MARTIN: Yeah, I was teeing you up.

MEMBER PALMTAG: I realize you're being very safe about safety here, but what we're kind of looking for, I mean good presentation here, you're following the procedures, but we're kind of looking for some more details on this. So, specifically the point connection model, your stability is going to be a point connection model. Point connection parameters have to come from somewhere, and you're saying this is from some other model. Can you give us some more? Where exactly are these point connection models coming from besides just some other model?

MR. LUO: So, basically -- this is Hugh Luo from TerraPower. That came from our core design methodology, so they are using different computer codes, so I'm not the expert for that, so I would not mention specific codes, the name. But we do have specific code design that's doing those calculations, and that also goes to the verification and validation process.

CHAIR ROBERTS: Can I just ask one

question? Sorry, just one quick question. Do you know, are we going to see this core design methodology report? Is that one of the things we're going to review, or?

MR. ANZALONE: This is Reed Anzalone from the staff, it's part of the construction permit application.

CHAIR ROBERTS: Okay, so we're not going to see that until the construction permit, okay, thank you. All right, sorry, continue.

MR. JARRETT: Yeah, I mean do you want us to answer -- so, this is Mike Jarrett from TerraPower, core design analysis. I think Mark was also speaking up on the Teams call, but yes, so we're using, to get all those reactivity coefficients that go into the point kinetics model, we're using a 3D variant, so it's a variation on that old transport code.

So, we're doing a 3D neutronics steady state calculation, we're basically doing direct perturbation, so we'll perturb the axial length of the fuel in that model, calculate the change from activity, get a reactivity coefficient from that, and that's what we feed to the SAS model.

MEMBER MARTIN: So, that growth also comes with more of a flowering, right? It pulls that so you can capture that, that growth is not just straight up.

MR. JARRETT: So, we account for axial expansion, and then we also account for radial expansion separately, so those are two different reactivity coefficients. So, we have a Boeing model that's called Rainbow, I think that also may be -- so, it's not going to be in this topical report. But so yeah, we have a mechanical model that models the actual mechanical movement, the displacement of the fuel.

And then we have a neutronics model that calculates the reactivity of those mechanical displacements.

MEMBER PETTI: And we heard about the mechanical in the fuel qualification topical, hopefully we can see the pieces coming together here.

MEMBER MARTIN: Thank you, that was helpful. It's nice to see some idea of what these parameters are.

MEMBER PALMTAG: I want to go back to what Dave was talking about, I had a question on what Dave was talking about. So, we're talking about the geometry effects, and the geometry effects don't scale, and I think you're being really careful in your answer, you're talking about how you want to be careful on how they do not scale.

But this is a public meeting, and I don't want to give the impression that you're doing something really strange here. This is a normal sodium fast reactor, hexagonal core, fuel pins, wire wraps. Can you give us some -- you're not going too far of our experience basis on this core, giving you a chance to sort of let people know that you're not going too far outside of our experience.

MR. SCHULTZ: I think it falls within the description you just gave. We talked about how EBR2 is not an adequate integral test facility. We just talked about it, and how it has some components that are different from Natrium, which are in terms of the flow path, and probably one of the worst things to say about EBR2 is just the fact that it doesn't have visual uncertainties, some of the data is missing, things failed.

It's an old facility, so we've used it as a basis for performing calculation to look at when SAS is capable of calculating -- and of course Argonne did that as well, and it can do that. But you've got a lot of questions when you get finished because the things that you're missing. So, it's not a question of Natrium being so different, it's more a question of what's available.

MEMBER PALMTAG: There are some different changes, but I do want to say that we are confident in our design basis, and just to kind of give a for public reference, we've got EBR2 is small, it's 62 megawatts. The original PRISM design was, I can't remember, 467, you're 482, FFTF was in the 400 megawatt thermal, and then you have Super Phenix 2000, so this is sort of a standard fast reactor, this is kind of in the middle. Hexagonal pins, hexagonal wire wraps.

MEMBER PETTI: I just want to say when you read the fuel qualification report, they went to great lengths to show how it kind of fits in the family, if you will. You guys are using it in a very strict sense of what scalability means in the context of 1.203. The non-expert could misinterpret what that means, I think that's why Scott is asking these questions.

Yeah, there are some differences outside of the core, but in terms of in the core, these things really look fairly similar to the historical.

MEMBER SUNSERI: So, this is Sunseri, and I just want to add, I know the perspective here from my view, I'm an operations guy, I'm not a physics guy or anything like that. What I hear you describing is a process to arrive at an outcome, and it's very similar in my mind, I'll use the analogy of the systematic approach to training in the qualification of operatives

Five step process, analyze, design, develop, implement, and evaluate. We're kind of hung up on the evaluate here because we don't have the results yet. So, this group didn't come in here to explain the outcome, like the qualification of an individual operator and the grade he made on the test, right? They're describing the process to train and qualify that operator.

All these questions we're asking, I think are about the outcome, which will come at different presentations when we get into details of the design. Am I close on that assessment?

MR. SCHULTZ: Yes.

MEMBER SUNSERI: Okay, thank you.

MR. SCHULTZ: Exactly.

CHAIR ROBERTS: Yeah, and I think you're exactly right. I think this is probably a good time to wrap up the presentation from TerraPower, because we still have to hear from the staff, and I think we're going to be hearing the same basic story from them, which is that this is a process, and they have reviewed the adequacy of the process, and it followed with a lot of work yet to come.

And they expect that process will lead to an acceptable outcome. So, with that, my proposal is we're about half an hour behind schedule and we still need to hear from the staff, so I'll look at kind of the stink eye glances I get from people, but my inclination is to push on, and get done with the staff, and then make our break, and then move onto the stability topical report.

I'm not hearing any major objections. So, Trevor you've got one slid yet to go, I think it's just summarizing what we've been talking about. So, you can either present it, or just go on and say you're done, and then we'll move onto the staff if that's fine with you.

MR. SCHULTZ: Sure, yeah, that's correct.

CHAIR ROBERTS: Your mic.

MR. SCHULTZ: Sorry, I thought it was putting out the green light. So, yes, that's correct, we just have one last, it's a conclusion slide, it just summarizes what we've been talking about. So, can you put it up please? There it is, okay. So, our methodology alliance with the regulatory guidance. Of course the self-imposed regulations are common sense really.

This is applied to Natrium, understanding of the verification and validation assessment information will be provided once we have all the data, and we'll perform the calculations.

CHAIR ROBERTS: Yeah, thank you. So, and TerraPower, if you could move out of the way, let the staff take over the little table. A couple of free minutes for the transition between TerraPower and the staff. And then staff, as you go through your presentation, I think it's 33 slides, but a lot of it is duplicative of what we just heard, so if you could keep that in mind, and focus on what we didn't hear, appreciate it.

Okay, with that, we'll take a couple minute break for the staff to come on, and once they're here we'll do that.

(Whereupon, the above-entitled matter went off the record at 10:03 a.m. and resumed at 10:04 a.m.)

CHAIR ROBERTS: All right, it looks like the staff is up and the slides are up. So, let's go ahead and restart. Roel, you're going to --

MR. ANZALONE: Roel's going to kick it

over to me. We seem to be missing some members, should we wait another minute or two?

CHAIR ROBERTS: Let's go ahead and get started.

MR. ANZALONE: Okay. So, my name is Reed Anzalone, I'm a senior nuclear engineer in Advanced Reactor Technical Branch Two in the Division of Advanced Reactors. I'm the overall technical lead for the TerraPower Natrium design, and the Kemmerer Unit One construction permit application, and I'm also involved in the review of all the topical reports that you're going to see this week.

So, I did want to give a little bit of context sort of in that capacity about the stuff we're going to see today. And I think, Member Roberts, you kind of hit on some of the stuff right at the very end there that I think is instructive. Which is I think that we have been pretty open about the fact that this is a process, these topical reports, especially the DBA methodology that we're going to see today.

And the other topical reports tomorrow lay out kind of how they plan to use them, and verify, and validate them as time goes on. And as the codes, or the methodologies and the design matures, I think that this is not done to the extent that we would expect it to be done at an operating license, but we think that it's okay for a construction permit, for those things to mature in parallel.

So, I just wanted to lead you with that. Based on what's in our regulations in 50.34 and 50.35 that make it clear that we can accept an application and grant a construction permit in instances when there is information that can reasonably be left for later consideration at the operating license stage, and that there is a research and development program that exists to close gaps, and answer any outstanding safety questions.

Unless there's any questions about that, I would turn it over to Roel and Alec.

MR. BRUSSELMANS: Good morning everyone. My name is Roel Brusselmans, I'm a licensing project manager on the TerraPower Natrium project, and I'm the lead project manager on the review of the two topical reports that are being discussed today. Sitting with me for this presentation is Alec Neller, he's an NRC nuclear engineer, he's responsible for the technical review for the DBA for in vessel events without radiological release.

And also sitting next to me is Reed Anzalone who introduced himself a moment ago. Next slide please. This slide describes the agenda of the NRC staff's presentation for this topical report. We will provide an overview of the chronology of the staff's review, discuss the purpose, and review strategy for the topical report.

Give an overview of the regulatory requirements and guidance, give an overview of Reg Guide 1.203, discuss an overview of the safety evaluation, the limitations and conditions, and the safety evaluation conclusions. Next slide please. Regarding the time line of this review, after a pre-submittal meeting in June, 2023, TerraPower submitted revision zero of the topical report in September of 2023.

The NRC staff accepted the topical report for review, and began the staff's review in October of 2023. The NRC staff conducted an audit of the topical report March through June of 2024. Following the completion of the audit, TerraPower submitted a revision to the topical report to resolve issues identified during the audit.

The NRC staff's draft safety evaluation report was issued on December 23rd of 2024. Next slide please. If there are no questions, I'll turn it over to Alec.

MR. NELLER: Hello, this is Alec Neller. TerraPower talked a lot about the purpose of this topical report, but really for our review strategy what we did was basically look at each step of the EMDAP, and compare what TerraPower did with the guidance in Reg Guide 1.203.

For regulatory requirements we were relying on 10 CFR 50.34(a)(4), which requires preliminary analysis and evaluation of the design and performance of SSCs of a facility, especially in their construction permit application. And then 10 CFR 50.43(e), which requires demonstration of safety features through performance, through analysis, tests, programs, experience or a combination thereof.

As well as requiring sufficient data exists regarding safety features of the design to assess analytical tools for safety analyses over a range of plant conditions.

MEMBER MARTIN: So, Alec, I know Reed addressed this -- this is Bob -- already addressed this to some extent, but you pick up the TR, and you'll see a lot of TBDs for about maybe half of the different steps, and you said each step is something -- looked at every step for adequacy. So, I kind of infer from that that ultimately it's really the -- for kind of the standard acceptance for the review, and you're really looking at the first couple elements, really more of the top down aspect, and then a plan for bottom up, is that fair?

A characterization that if you had to pick some kind of a chest for sufficiency, are you basically saying kind of the top down aspect of the evaluation model is sufficient? Which once upon a time that was good enough, right? So it's only been 35 years that we've kind of thought a little bit broader.

MR. NELLER: I would say for this our focus definitely was the beginning few elements, we're really looking through step 11 or 12 with a lot of adequacy compartments yet to be done. I would say the main focus was looking at step seven, and really developing the EM assessment matrix. I think a lot of it is more top down, but I think we'll get into a bottom up approach in the future, which we would like to see before the OL.

MEMBER MARTIN: But I mean they can get a CP before then, is that your feeling?

MR. NELLER: Yeah, that is my -- with what I have here, yes.

MEMBER MARTIN: A lot of us don't have a

lot of experience with what is that measure, and what is enough --

MR. BRUSSELMANS: And I mean, I will say to be totally honest, not that we're charting new territory here per se, but this is not something that the staff has a lot of recent experience with either, except for RTRs that we've issued construction permits for recently. So, we have had to think about this a bit. I will add I guess I wouldn't necessarily characterize it as a top down versus bottom up, but more like flowing through.

And I feel comfortable saying that we have confidence in it when we've identified the code that they're going to use, we know that it's well understood, and that they've identified the key phenomena for the transients that they're looking at, and that they have identified at least existing legacy data, and or filled the gaps with IETs and SETs, which they have at this point.

So, to me, or to us, for a construction permit application, that feels like a good place to be.

MR. NELLER: So, moving forward, we heard a lot from TerraPower on Reg Guide 1.203, this provides guidance for developing your EMDAP, and just for public evaluation model concept, that's really we're just looking at the calculational framework for evaluating the behavior of the reactor system during a postulated transient or accident.

It includes not just the computer codes, but also all the other information needed to apply the framework to a specific event, and we'll be looking at all four elements, which TerraPower has discussed. Regarding element one, we're looking at identifying what the application envelope is going to be determining those figures of merit, and then identifying what important phenomena and processes need to be evaluated, and included in the EM.

For step one, Reg Guide 1.203 calls out specifying the analysis purpose, transient class, and power plant class. And TerraPower really discussed what they're doing with this step. I just want to note for the transient classes, what we really looked at was ensuring they encompassed the correct DBAs had been done in the past.

And so, we looked at loss of offsite power, that really encompasses loss of flow casualties or accidents, rod withdrawal at power, encompasses reactivity addition, accidents or events, and loss of heat sink encompasses loss of cooling events. And with that we looked at past licensing experiences, such as the PRISM reactor.

And with all that we determined that step one meets the guidance provided in the reg guide. However, we did limit the applicability of the EM, and of the topical report as a whole to the Natrium design, as described in the topical report and the SE. And we'll talk more about the limitation conditions at our conclusion.

For step two, figures of merit are determined, and those are quantitative standards of acceptance used to find your acceptable answer for a safety analysis. And TerraPower talked a lot about three FOMs they picked. Really what I want to highlight is that the TATNF criteria is primarily used to screen whether a DBA needs further analysis.

So, if something passes this evaluation model, we don't expect any sort of radiological release from the cladding, from the fuel to the coolant. And we're in the process of reviewing the DBAs with release right now. And for this report, we went ahead and audited internal documents detailing patent development, and we determined that these figures of merit were acceptable and adequate because they can be used to ascertain whether there is any sort of fuel failure, and whether a phenomena would challenge the primary coolant boundary.

MEMBER PETTI: Alec, just a quick question on that. You also looked at -

MR. NELLER: Someone's mic is on.

MEMBER PETTI: You also looked at any sort of fuel performance calculations then, to look at strain, and cladding waste, the tool that they're going to use for that?

MR. NELLER: Yeah, TATNF really --

MEMBER PETTI: It's not in the topical at all.

MR. NELLER: A lot of that we looked at in the DBAs with release audit. But yeah, we have reviewed basically how they got TATNF, how they built on strain, cladding waste, and thermal creep.

MR. ANZALONE: I would say it's a mix of what's in that DBA with release topical report, and what was already covered in the fuel qualification.

MEMBER PETTI: Okay. It's hard to slice these things.

MR. ANZALONE: Yeah. And we can go into more detail about some of this stuff in the closed session if that would be helpful.

MR. NELLER: Yes, and so overall we found that the approach to step two was acceptable. Moving to step three, Reg Guide 1.203 really talks about performing your hierarchical system decomposition, where you break the system into subsystems, subsystems into components, et cetera. And so, TerraPower provided their hierarchical decomposition to the Natrium plant.

And we really looked at this decomposition and compared it with the description of the plant in the topical report to make sure all necessary ingredients were included, and we found that in fact step three was completed acceptably. For step four, as TerraPower discussed, this is where you perform your PIRT, you look at what sort of key phenomena are out there, and you rank them based on importance and knowledge level.

As they discussed, they have this composite PIRT which encompassed a series of two internal and three external PIRTs. And we really did a deep dive into auditing those to see what they did, and for these PIRTs, for each of the accident scenarios, they identified three different characteristic time periods, and then looked at important phenomena and processes for each time period, and for those processes they were ranked based on importance and knowledge.

MEMBER MARTIN: So, you heard me earlier ask about the state of knowledge, and how really it was just high and medium, you didn't notice that, and kind of question one, the use of state of knowledge, and their decision making, and two how little fidelity there is in a state of knowledge that is basically just high and medium?

MR. NELLER: Yeah, there are some that I guess a lot of the specifics of what phenomena are high or low we talk about a fair amount in the closed session. But we did review the ones that were low, if they were high importance, medium knowledge, we did look at those a little closer, and we really focused on the scaled experiments TerraPower has planned to make sure that if there was a gap, or if there was a phenomena that seemed to have maybe less knowledge, that they were covered.

MEMBER MARTIN: For instance the rod growth question, I would consider that pretty much low, but that's not on there. But it didn't come up.

MR. ANZALONE: Well, I would say that that's more of like an input to this methodology rather than part of the methodology itself, because it's part of the fuel performance and core design modeling.

MEMBER MARTIN: It's still an input, it's an important input.

MR. ANZALONE: I won't disagree with that.

MEMBER MARTIN: Right, I mean that's the -- all these things have to fit together, they're not silos. So, you have to -- I mean you guys get to see them all too, more so than we do, and you kind of have to go all right, I saw this in fuel, this is going to carry over in safety analysis methods, and you should expect to see important things there become important elsewhere.

MR. ANZALONE: So, I mean, but you know as far as my understanding is, a lot of the dual axial growth that's part of the existing legacy data from the metallic fuel operating experience, to a certain extent, it's incorporated into the empirical models that exist there for that. So, I wouldn't say it's like an unknown phenomenon.

MEMBER MARTIN: Well, I appreciate the answer we got about the core design folks, but then it's just -- those are calculations, right? Knowledge really comes from more the experience, empiricism, the testing, the analysis one is a part of it, it's not all of it. And in fact if anything you're going to weigh the testing more than you're going to weigh the calculation.

But from a decision making standpoint, they're doing the right thing. Is it reflected in PIRT? And I'm not so sure, but.

MEMBER PETTI: I think this is like the space though, it is difficult, because there could be scaling effects, and also the restraint system here is not one we've yet to have, so there's an empirical sort of database from EBR2, and a little bit from FFTF, but the juncture here is a little bit different, and that's where I'm sure you guys are -- that's where the focus will be.

MR. ANZALONE: We have some slides to talk about that in the closed session.

MEMBER PETTI: Good. Just something before I forget it, there's a lot of discussion at higher levels about in the PRA space how much do you need for CP. But I think there's a lot of other areas where you could ask the same question, this is a classic. Reg Guide 1.203, I mean that's a pretty evolved resource intensive activity that an applicant has to do.

You guys are kind of setting potentially sort of a precedent. As you said, you've really only done research in test reactors, this is your first power reactor, it might be worth capturing it for an ISG or some other internal thing so that you're -- everybody has kind of the same rules of the road. Because I think there are some common elements that are going to bubble up here that should be captured, more a comment than a question.

MR. ANZALONE: Yeah, appreciate the comment.

MR. NELLER: Yes, and so moving forward, as I discussed, we audited the TerraPower PIRT development process, and we determined it was acceptable, and followed the guidance. We also looked at the phenomena that was identified, and we found them appropriate for the transients that TerraPower is considering for the EM, because they're consistent with the design, as well as past operating experience.

Especially the PRISM reactor, and the EBR2, FFTF. And because of those two things we determined that TerraPower's overall approach to step four and the PIRT were acceptable. Moving onto element two, this is where the assessment basis developed, and for TerraPower of course they included a combination of new and legacy experiments.

I would say a bulk of our work was really looking at what experiments were chosen, and making sure that they make sense for the phenomena that were identified in the PIRT. And we'll talk a lot about that in the closed session. And this assessment basis of course will be used for helping validate the codes as part of element four.

For step five, basically the reg guide calls out you want to determine your objectives for the assessment database, and that's basically set that should include separate effects test, as well as integral effects test. And so TerraPower clearly states in the topical report that their objective is to identify sufficient experimental data for their assessment base.

They determine scalability of category, as well as extending that for each phenomena, they want at least one category IET, and all necessary supporting SETs. They also identified additional category two and three scaling data could be provided to increase credibility for the evaluation model. And overall we determined that the objectives step five were adequate, and used guidance in the reg guide.

MEMBER MARTIN: So, in your audits, did you see some of their calculations and make at least notional evaluation of their progress on V&V and generally are satisfied with what you saw there or you were just kind of more focused on their plans and less on actual evidence at this point?

MR. NELLER: We looked at -- we focused more on the plans. There was some, a little bit of V&V data that we did look at, some calculations that were done, and we reviewed those as part of this as well, but it was primarily looking at the approach.

MEMBER MARTIN: Okay.

MR. NELLER: For step six, this is the scaling analysis that TerraPower discussed, and the reg guide, of course, calls out you want that top down as well as a bottom up scaling approach, and TerraPower provided an example of how they're doing the top down scaling approach using their hierarchical two-tier scaling system.

Overall, we found that this approach was acceptable. However, we did not make a determination with respect to the staff's execution as that has not been completed, and so that was our limitation condition two, which applies to maybe the later steps.

For step seven, this is where existing data is identified to include in the assessment matrix, as well as identifying what sort of IETs and SETs are needed to complete any sort of gaps that are out there and we like to see test data.

And, of course, the reg guide calls out that these experiments should address the important phenomena and you should have multiple tests to ensure that the evaluation model is not attuned to a single test.

And TerraPower, they included -- their planned assessment matrix includes data from a scaled IET, four scaled SETs which address various phenomena identified in the PIRT, as well as experience from previous operating SFRs and historical experiments.

And looking through all of the identified experiments, we did determine that there appears to be enough to provide adequate assessment data for all of the highly-ranked phenomena identified in the PIRT.

However, we did not make a final judgment on this step largely due to the scaling assessment from step six has not concluded. There are experiments still being performed, and, of course, the pedigree evaluation and code assessment matrix have not been finalized.

Moving on to step eight and nine, these steps again have yet to be performed. Step eight, you're really looking at IET distortions and scale capability. Step nine, you're looking at experimental uncertainties, and TerraPower outlines their plans.

They say that they're going to follow NQA1 for the scaled experiments and then look at the legacy data to determine degree of compliance with NQA1, and we found that the approach in these steps were adequate, but again, subject to the limitation in condition two.

Moving onto element three, this is where we focused on the evaluation model, looking at SAS and making sure it can analyze the transients that were identified in element one.

With this, we started with step ten, which the reg guide calls out that you should have an EM development plan created based on the requirements in element one, and it basically states that you should have standards and procedures that cover E6, the bullets listed there, things from design specifications, QA procedures, et cetera.

And for these, the topical report provides a high-level overview of what they're doing, and then we did audit internal documents looking at their design specifications and quality assurance requirements, and we determined that their approach to step ten was acceptable.

For step 11, this is where in the reg

guide you develop the evaluation model structure, and the reg guide calls out what the EM should include and be able to do, and a lot of these come from your step three, your hierarchical breakdown. In step 11, you go back to that and make sure that your EM can address all of those ingredients.

And as TerraPower discussed, they applied SAS as their main computer analysis code. And so, for this step, what we really did was take a deep look at the SAS manual and make sure it covered all six ingredients as discussed in the reg guide, and we did determine that their approach was acceptable.

Taking a quick look at what we did for this review, we took the step three hierarchical breakdown and basically compared it to what was in the manual and the topical report.

For the reactor core and core components, the basic geometric modeling element used in SAS is a channel consisting of your fuel pin, cladding, and the associated cooling structure on the panel. You can do a single pin or multiple pin model depending on how much fidelity you want within a given assembly or part of the reactor, and you can basically stitch those together to get your entire core.

For the other systems, the primary

intermediate coolant loops, you can model the overall reactor using compressible volumes that are connected with liquid or gas segments. These segments are broken up into multiple elements.

And some examples of those compressible volumes would be the hot and cool pool of the reactor, whereas elements would be things like pipes, heat exchangers, pumps, et cetera. We also verified that staff has the ability to model the reactor air cooling system, which is their safety way to keep themselves capable.

We also looked at -- SAS was developed for liquid metal reactors. It is capable of modeling liquid sodium in both the primary and intermediate loops. We looked at cover gas includes argon, and again, allows for air interactions with the RAC and includes the appropriate fuel equations as required from step three.

For step 12, this is where our closure models are developed and incorporated into the EM. As discussed in the reg guide, this can be developed using data from your SETs or they can be taken from existing database literature.

And in the topical report, what TerraPower does was they identified what current models are included in SAS that they're going to use, as well as discussing three new models they're going to add that were developed from literature.

And for these reviews, we looked closely at the SAS code manual for the existing closure models, as well as available literature that was cited in the topical report, and we also audited internal TerraPower reports to ensure that their fuel assembly design parameters fell within the range of applicability for each correlation.

And we determined that both the existing and newly added closure models were acceptable because they generally provide adequate predictions of key parameters and the fuel assembly design parameters fell within their use. Now, this step is subject to limitation and condition two pending results of further testing related to correlation development.

Moving on to element four, as TerraPower said, a lot of this is more just looking over their plans for assessing their EM adequacy. This includes both a bottom up and a top down approach. And for this, just to save some time, I'll do a quick discussion, but please stop me if you have any questions.

Step 13, this is where we're looking at

model pedigree and applicability. TerraPower provided an example closure relationship, outlining their considerations for each of these, and we found their approach acceptable, but again, this is subject to limitation and condition two.

For 14 and 15, the model fidelity and scalability are examined. Again, TerraPower provided their approach. They talk about performing SAS calculations and comparing them to their SETs that are part of the assessment matrix, and it has yet to be performed and thus is subject to limitation and condition two.

For step 16, this is where we get to that top down approach. They talk about how they're going to look at their fuel equation capabilities, how they intend to evaluate their fuel equations by performing calculations and comparing them to experiment scaled Natrium, et cetera, and again, we found their approach acceptable, but subject to limitation and condition two.

The same is true for 17 and 18 where again you continue your top down approach looking at the integrated code as a whole and looking if it's capable of modeling plant subsistence components.

For step 19, continuing with that top down approach, you do that scalability evaluation, which we have yet to determine whether it's acceptable again to limitation and condition two.

Finally, to slow down for a second, this is where we did a fair amount of review as well is looking at the conservative approach TerraPower has taken. For step 20, Reg Guide 1.203 calls out determining your biases and uncertainties of the evaluation model, including whether the degree of overall conservatism or uncertainty is appropriate for the EM.

And in the topical report, TerraPower discusses how they plan to take a conservative approach for the EM rather than performing uncertainty analyses. And they talk about how they ensure to do this by inserting conservative biases to the inputs related to highly-ranked phenomena, as well as applying hot channel factors to the output to obtain conservative cladding temperatures.

And I know they plan to talk about it more in the closed session, but we determined that their overall approach to step 20 was appropriate for ensuring inputs would be biased conservatively, as well as providing an overall conservative result.

And I wanted to note that Reg Guide 1.203

does call out that -- it states that suitably conservative transient analyses do not require a complete safety analysis.

And with that, of course, this is subject to limitation and condition two. All of this work still needs to be done, and to determine whether it's truly conservative, you want to see the experimental results compared to what the EM is giving out.

With that, overall, we determined that the topical report provides an acceptable approach for developing this methodology for applicants utilizing the Natrium design to evaluate MSO DBA events without radiological release.

We did subject it to limitations and conditions. The first is focused on basically limiting our conclusions of the SC to those using the Natrium design as in the topical report, including the use of type one fuel. If there's any sort of deviations from this, they have to justify that in a subsequent submittal. We additionally stated that this methodology was developed for LMP as discussed in the topical report and NEI 18-04, so using this methodology for other kinds of analyses would also have to be justified.

For limitation and condition two, this is kind of a catchall that states that certain steps or parts of the topical report have yet to be completed, and as such, anyone referencing this methodology would have to justify that this is at an acceptable stage for its intended licensing application. And with that, as we discussed, this is really saying we think it's ready for a construction permit application, but for an OLA, more work needs to be done.

MEMBER MARTIN: Member Martin here. Do you expect any of those steps to be kind of closed as part of the CPA? Reed, you noted a couple of examples where you'll get information in the CPA that may not otherwise appear in the methods' documents.

MR. ANZALONE: I guess I don't know if I could say that I would expect them to be closed as part of the CPA. I think they would become maybe more clearer or more multiplied.

MEMBER MARTIN: Okay, might as well hedge a little bit.

CHAIR ROBERTS: Okay, any more questions for the staff from the members or consultants? Not seeing any, we're a little behind schedule, so let's take a break until 10:45, 11 minutes instead of 15, and then at 10:45, we'll restart with TerraPower to work on the nuclear humidity output. We're now in recess until 10:45.

(Whereupon, the above-entitled matter went off the record at 10:34 a.m. and resumed at 10:45 a.m.)

CHAIR ROBERTS: Okay, it's now 10:45 and we're back in session. We have TerraPower. They're going to present on the stability methodology topical report. Josh, are you going first?

MR. RICHARD: Can you all hear me okay?

CHAIR ROBERTS: Yeah, go ahead.

MR. RICHARD: Great, my name is Josh Richard. I work at GE Vernova Hitachi and I'll be presenting on the Natrium stability methodology.

So, our purpose today is to provide a description of the methodology built to characterize Natrium reactor stability, leverage this methodology in subsequent licensing interactions, including the CPA and the FSAR, subject to limitations specified. Next slide, please?

So, we'll begin by a brief discussion of where our top-level regulatory criteria comes from. It comes from Natrium principal design criterion 12, which states that the reactor core, associated structures, associated coolant control and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable system radionuclide release design limits, SARRDLs, are not possible or can be reliably detected and suppressed.

The methodology will be used to demonstrate that power oscillations with the potential to exceed SARRDLs are not possible, so we're focusing on that first component of the PDC. The Nyquist stability criterions and figure of merit is used to assess the stability of the system.

The figure of merit defines the system as unstable when the open loop transfer function, also known at the OLTF, encircles or passes through the negative one plus zero J point on the complex plane, which is also referred to as the singularity location, and the graphic on the right there has an example diagram of what an unstable system response would look like. Next slide, please?

MEMBER PETTI: Just a quick question from the non-reactor physicist. I was talking to some reactor folks a couple weeks ago about stability across reactors, and we tend to think of boiling water reactors, sometimes heavy water reactors, and I said well, is it an issue in sodium? And they said no.

And I thought to myself why am I reviewing this report then? I mean, is it -- it's not inherent? I mean, there's a good phase space, if you will, that sodium reactors can be stable, but there's places that are not good? How do you characterize it in the generic sense?

MR. RICHARD: Your inference is correct. We do not expect to observe any stability challenges with the Natrium system. However, we still need to show compliance with PDC 12, so, yeah, that's right. All right, so -- oh, go ahead.

MEMBER MARTIN: Member Martin. Nyquist stability, is that inherently assumed kind of on the linear response, and do we have any non-linear characteristics that complicate the stability analysis?

MR. RICHARD: That's an excellent question and we'll get more into this in the closed portion, but our methodology is intentionally constructed to interrogate that very question.

MEMBER MARTIN: Okay, great.

MR. RICHARD: Great question. Yes, it does inherently assume linear response. So, our goal with our methodology's evaluation approach is to sample the full range of inputs to ensure Natrium reactor stability over all anticipated conditions.

Nyquist is our figure of merit, so that means the methodology yields a set of Nyquist results characterizing all anticipated conditions on a stability map.

Now, that open loop transfer function, the OLTF, that comprises the Nyquist plot, consists of two principal components, the zero power transfer function, also known as the ZPTF, and the full power transfer function, also known as the FPTF, and I'm going to say transfer function a lot today.

The ZPTF is a measure of the reactor power response gained in phase shift relative to a sinusoidal reactivity input in the absence of radioactivity feedback effects, while the FPTF is that same gain in phase shift in the presence of radioactivity feedback effects.

And this is sort of a visual example of what a gain and phase shift are physically speaking. We've got a diagram here on the right side of the slide. The input signal of reactivity is shown in blue. The output signal of reactor power is shown in orange.

The gain is proportional to the difference in amplitude between the input and output sinusoids, and the phase shift is proportional to the time lag in those sinusoid peaks from the input to the output signals.

MEMBER PALMTAG: This is Scott Palmtag. Real quick question, I agree with all of this, but all of the point kinetics equations, all of the point kinetics parameters are difference in these cases too, right?

MR. RICHARD: So, for the way we model our full power transfer function and our sub power transfer function, we use the same point kinetics parameters. At the particular -- well, I should say we use the conditions that are appropriate for the statepoint model, so at a particular power float condition.

Now, your question around notable change for zero and full power, the zero power transfer is kind of an approximation. It's sort of a notional thing to say if we neglected feedback effects at a given power and flow.

So, even if we're modeling a full-power condition, if we act as if the point is zero power, there's no feedbacks being included in that particular calculation, but the point kinetics parameters still include that particular initial condition's power and flow characteristics.

So, it's a bit of an artificial imposition that says for the zero power, analyze the same point kinetics equations, just don't include the effects at a particular power flow condition.

MEMBER PALMTAG: The reactivity feedback point is not -- you're saying the reactivity feedback. Is that the point kinetics or is that the temperature input into --

MR. RICHARD: That's the temperature input. That's right. Yeah, so for us --

MEMBER PALMTAG: It's still point kinetics.

MR. RICHARD: Still point kinetics, just with or without temperature feedbacks.

MEMBER PALMTAG: And the parameters are the same whether --

MR. RICHARD: The parameters are selected based on the initial condition, which --

MEMBER PALMTAG: For each one of your statepoints --

MR. RICHARD: Each statepoint will have --

MEMBER PALMTAG: -- is going to have a different 3D model which is going to edit out your point kinetics problem. Okay, thank you.

MR. RICHARD: Next slide, please? Now,

looking briefly here about the benchmark exercise we performed with the Fermi 1 oscillator rod measurements.

Fermi 1 was a commercial power reactor and operated in the 1960s, a sodium fast reactor. Similar to Natrium, metal fuel, sodium coolant. It was a fast spectrum system and operated at a power level of 700 megawatts thermal.

During startup testing at Fermi 1, oscillator rod measurements were performed where they applied a sinusoidal reactivity input using the device shown on the right. The XY view is probably the easiest for you to see what the device actually looked like.

The cylinder possessed a region of absorbent material. That's kind of the top bundle of seven pins in that XY view, and then in the bottom part of that cylinder, there was a region of reflector.

As that cylinder was spun in the reactor, that's what introduced the sinusoidal reactivity input. They applied that sinusoidal reactivity input at frequencies ranging from five hertz all the way down to 5e-3 hertz, and they did this for both the zero power and the full power transfer functions.

They operated it both at lower power levels and at full power levels. We evaluated our methodology with this benchmark, and that evaluation showed good agreement once we applied Fermi 1 specific model refinements.

We have two identified limitations that we paraphrase here in the bullet portion of our presentation. The first limitation discussed is how inputs provided to the methodology that are calculated by other methodology, so, Scott, referring back to core design, the full three-dimensional, those were captured at a higher fidelity behavior. They identified important phenomena and that are consistent with their incorporation into this methodology.

Now, limitation two directs that the specific application of model uncertainties must be reviewed and approved by the NRC, and we'll discuss those more in detail with the actual language in the closed portion of the presentation.

MEMBER PETTI: I have a question. I look at some of the stuff that was done back in the '60s. This is amazing. Do you know why they did this stuff? I mean, were there questions about stability back then?

I have a vague recollection of a professor telling me that in the early days, they just didn't know if the fast reactors would actually, from a reactivity perspective, be stable like a lot of reactors that had been built up to that time. Is that --

MR. RICHARD: That's my understanding, that they just wanted to be extra sure and explore that full potential space.

MEMBER PETTI: Interesting.

CONSULTANT SCHULTZ: This is Steve Schultz, and another general question. There's a lot of information that was discussed, presented, associated with the overall evaluation from EBR2, and looking at the EBR2 data sets associated with stability, just a question, why was the Fermi 1 database selected versus EBR2? Did you look at the EBR2 database associated with their evaluation of stability?

MR. RICHARD: That's an excellent question, and yes, we have been reviewing additional benchmarks in addition to Fermi 1, but we selected Fermi 1 for presentation in the topical report itself because of the great degree of similarity between the two reactors, especially in terms of the reactor size and the core materials, the fuel material, the coolant material all being highly conductive metal materials in the core. Those are important for the time constants that feed into the stability analysis and those have high degrees of similarity.

CONSULTANT SCHULTZ: Thank you. Yeah, I understood there were some similarities in design. The EBR2 database looked extensive and you referred to some references associated with pieces and parts of that, and of course, the overall approach for stability evaluation was similar for each of the design evaluations. Thank you.

MEMBER MARTIN: Member Martin. The PIRT phenomena related to, say, flow distribution or redistribution following a reactor trip, and looking at even the notional diagram of the pool, there's equipment in there. You know, there's a couple pumps, heat exchangers.

It's not kind of the ideal pool that you might otherwise see, although it's fairly large, and, of course, those obstructions could contribute to, say, asymmetric cooling and flow in the core for the long-term cooldown portion of any event. Could you have, say, local instabilities where maybe the flow is stagnating a bit maybe on the periphery where it's slightly cooler than, of course you know again --

powers everything.

So, but in the smaller reactor, you would, of course, expect the cooler periphery, hotter center, but if you get some asymmetry with the flow distribution, it might be hot here for a while and then the reactor circulation kicks on and it might stall somewhere else in the core.

Again, it's kind of a local stability. Was that part of this investigation that you -- you know, did the stability methods that you come up with look at that?

MR. RICHARD: It's an excellent question. I think we can get more into the details around particular feedbacks and phenomena in the closed portion.

MEMBER MARTIN: Okay.

MR. RICHARD: But I will say that general speaking, the methodology focuses on a relatively narrow event definition. So, again, like I was mentioning, we looked at an event at a particular initial condition of power and flow, and we introduced a very small reactivity sinusoid on that initial condition, so it's almost like a quasi-static analysis. So, it's dynamic, but it's a very, very small perturbation around a mean, but we'll answer your question more fully in the closed portion.

MEMBER MARTIN: Okay.

MR. PFEFFER: This is Scott Pfeffer, GE Vernova. So, just a note to add to that, I think it comes down to also what events are getting us to a condition where we're still having fusion power at nuclear power and having those flow instabilities versus just --

Right, if we're doing pump trips and things, we're probably in a scram space for most of the events through those event definitions, so it depends on where, you know, it depends on how those event definitions line up with the steady state condition, but for the most part, those were necessarily included.

MEMBER MARTIN: Okay.

MEMBER HARRINGTON: This is Craig. I think that answers my question in my head. Again, not being a modeler, but in doing this, when you insert the reactivity organization, you keep everything else constant, right, the secondary and everything else, when most transients in nuclear power plants are initiated on the secondary.

Is it because of the huge time constant between, the coupling between secondary and reactor plant? There's really no concern there from the standpoint of rapid feedback from the secondary? Is that why you held it constant?

MR. RICHARD: It was irrelevant. That's a correct assumption. I think that in the closed portion, we can talk a little more in detail about particular ways we do try and treat the secondary side, but also again in general, the perturbations we're talking about are kind of an assumed perturbation that could come from any source, so that's the way we introduce.

We don't propose that it's coming from any one particular location. We assume that it comes in from somewhere and we want to see the reactor power response to it.

MEMBER HARRINGTON: Okay, because they're not always sinusoidal --

MR. RICHARD: Right, they're not. That's why we looked at multiple frequencies, and so ultimately, the full suite of our plots show what happens anywhere in that frequency range, and oftentimes, real plane transients like we're talking about will have some supposition of those frequencies, so, as long as we analyze the full range appropriately.

MEMBER HARRINGTON: You can bound it pretty well.

MR. RICHARD: Exactly.

MEMBER HARRINGTON: Thank you.

MR. PFEFFER: And again, I'd add to that too, it comes out of the event definitions, Craig, you know, from like BWR stability reads to, you know, pump trips. You're still in the operating range technically, right. You can be in extra circulation. We don't necessarily have that same event where we are in the steady state operation with pump trip, right, where we can have that operation.

So, most of the transient events will have immediate responses from a safety perspective, whether that's scram or something else analyzed in the DBA space, and don't get to a space where you're ever in a condition to start sitting there and oscillating.

So, you know, if we do, that means you're in the operating space. We expect to cover anything related to AOOs and normal operation in terms of that pseudo-steady state, including any off normal conditions, and then analyze it from that perspective.

MEMBER MARTIN: Member Martin again. One of the concerns you might have with a stability issue could be flow-induced vibration of the core, and I'm conjecturing. Can you weigh in on how much that was considered in your look at this? Are there other aspects, say, in the design of the fuel itself that kind of nip that in the bud and that's a perfectly good answer to that?

MR. RICHARD: Yes. Nothing proprietary, yes.

MEMBER MARTIN: Okay.

CHAIR ROBERTS: If there are no other questions for TerraPower from members or staff, that puts us exactly on schedule to transition to the staff's presentation on this topical report. So, you all can get in front of the table there, and Roel and Reed, I guess. We will break for about ten minutes again to line up the presenters and the slide deck, and we'll get started in about ten minutes.

(Whereupon, the above-entitled matter went off the record at 11:01 a.m. and resumed at 11:02 a.m.)

CHAIR ROBERTS: Okay, go ahead and get started.

MR. BRUSSELMANS: Okay, everyone, good morning again. For the record, my name is Roel Brusselmans. I'm a licensing project manager at the NRC assigned to the TerraPower Natrium project.

Sitting with me for this presentation is Reed Anzalone, who you heard from this morning. Next slide, please?

This slide describes the agenda of the NRC staff's presentation today. We will review the chronology of the staff's review, the purpose of the staff's review, the staff's review strategy of the topical report.

We'll also provide an overview of the contents of the staff's safety evaluation report, and then summarize the NRC staff's conclusion regarding the TerraPower stability methodology topical report. Next slide, please?

Regarding the time line of the review, after a pre-submittal meeting in June 2023, TerraPower submitted Revision 0 of the topical report in November of 2023. The NRC staff accepted the topical report for review and began the staff's review in February of 2024. The NRC staff conducted an audit of the topical report in May through July of 2024.

Following the completion of the audit, TerraPower submitted a revision of the topical report to resolve issues identified during the audit. The NRC staff's draft safety evaluation report was issued on January 31, 2025. Next slide? With that, if there are no questions, I'll hand it off to Reed.

MR. ANZALONE: I'm going to apologize in advance for this being a deeply unsatisfying public presentation because we put so much off to the closed session, but I'll answer whatever questions I think I can. I am going to try to stick pretty close to the slides though.

So, the purpose of the topical report, TerraPower already discussed. You know, we're describing the methodology used to characterize Natrium reactor stability, and as TerraPower said, this isn't necessarily something that we expect to have an issue with in an SFR, but it is something that needs to be looked at to assure compliance with PDC 12, which I'll get to in a couple of slides.

Our strategy for the review was to evaluate the theoretical underpinning and look at prior uses of similar analytic methods, evaluate the treatment of uncertainties, which is something that was touched on in the previous presentation, review the demonstration of the analytic methods and the uncertainty treatment, and evaluate the operating reactor benchmark against Fermi 1, which was touched on also.

A quick overview of our safety evaluation, so we have per usual, a regulatory evaluation. We have a summary of the topical report, our technical evaluation which talks about the operating domain and frequency domain that were chosen for the analysis, the uncertainty treatment, and the benchmark evaluation L&Cs and conclusions.

So, the real governing thing, as I mentioned here before, is PDC 12, which was brought up in the last presentation, and the topical provides methods to demonstrate that the reactor is stable in all conditions of normal operation, including AOOs.

Detect and suppress solutions are mentioned in the PDC and at a very high level in the topical report. That wasn't really part of the review. That would be outside the scope of the topical, and so it was outside of the scope of our review.

I'll just talk briefly about the relevant design features here, and these will be more relevant when we're talking in the closed session, but it's a pool type sodium cooled fast reactor with metallic fuel, and that gives it a tightly coupled neutronic performance. The key reactivity phenomena really act on a core-wide basis primarily.

So, our conclusions were that it provides an acceptable methodology for assessing stability. It's an acceptable means to characterize and discretize the power to flow operating domain, including characteristics to indicate when a more detailed discretization of the power to flow operating domain would be necessary.

An applicant implementing the methodology would justify the selection of the frequencies that are analyzed to each statepoint. The theoretical approach is consistent with past stability issues that we found.

The methodology includes an acceptable means to characterize the input model uncertainty and justify these means, and I'm sure we're going to get into that in the closed session, and there's an acceptable evaluation of the benchmarking exercise against Fermi 1 and we will talk about that as well later.

The proposed limitations and conditions, we put them here. I think the previous presentation did a better job of summarizing them rather than putting them here because I don't think they make a whole lot of sense outside of the proprietary context, so I'll just flash them on the screen and we can talk about them more later.

And quick acknowledgments to RED/DSA. Pete Yarsky helped a lot in the pre-submittal meeting and wrote up some good findings for us, and then Ben Parks and Inseok Baek aren't here today, but they were instrumental in this review. So, that's it.

MEMBER PALMTAG: This is Scott Palmtag. There are quite a few questions on point kinetics.

MR. ANZALONE: Yeah.

MEMBER PALMTAG: It's a tightly coupled core, but I'm curious why you didn't require something more modern like a 3D kinetics model?

MR. ANZALONE: I think we can talk about that more in the closed session. Like I said, it's going to be a little unsatisfying.

MEMBER PALMTAG: Did you consider events where you would need a 3D kinetics model?

MR. ANZALONE: I think, and I'll piggyback on what Josh said in the previous presentation, that I think because of the events that we're thinking about that are initiated from like a sort of steady state normal operating condition, that it's not really the prime concern for the stability transients that we're looking at in this methodology.

MEMBER PALMTAG: Would there be any cases where you'd have an in-core stability, you know --

MR. ANZALONE: Not that --

MEMBER PALMTAG: -- top to bottom, left to right?

MR. ANZALONE: Not that jump out to me.

CHAIR ROBERTS: Any other questions?

MEMBER MARTIN: Did you have any requests for additional information on this topical?

MR. ANZALONE: We didn't, but we did explore a bunch of stuff in audit space, and they proposed changes to the topical report in response to that and submitted an update to it. I think there was some clarity added on what was being sought with the uncertainty evaluation among other things.

CHAIR ROBERTS: If there are no other questions for staff, that concludes the presentations in the open session on these topical reports. Now is the time to go out for any comments from the public, so if anybody in the public or in the room here would like to make a comment, go ahead and unmute yourself, state your name and affiliation as appropriate, and then make your comments. I see Dr. Lyman has raised his hand. Go ahead, Ed.

DR. LYMAN: Thank you. This is Edwin Lyman from the Union of Concerned Scientists. Can you hear me okay?

CHAIR ROBERTS: Yes, Ed. Go ahead.

DR. LYMAN: Great, thanks. Yeah, so moving backward, so allow me to register my great dismay with the presentation we just heard from the staff. I continue to be deeply concerned about the amount of information that is being withheld from the public about critical safety aspects of this reactor design.

TerraPower made commitments in earlier public meetings that they would try to be as transparent as possible, and the fact that so much critical information is not being made available to the public only raises my suspicion that they're trying to conceal just about everything that they don't want the public to see, and I'm skeptical that this is really a proprietary issue as opposed to a public disclosure and transparency issue.

So, in that context, I'm surprised that the staff would not make a greater effort to write a non-proprietary version that does make sense as a standalone document even if it is more general in scope, but to have essentially a completely incomprehensible set of limitations and conclusions to the public is not acceptable.

Now, going back to the first topic of the day, similar to comments I've made regarding fuel performance topical reports, I'm concerned the staff says it's okay for the construction permit to go forward and be approved even though the underlying safety analysis codes have not even been verified and validated, much less have produced any useful safety information.

In the context of an application that is pursuing the licensing modernization process where the safety analysis is supposed to be deeply informing the design of the reactor, it does not seem appropriate to base the design for a construction permit on safety analyses that don't even have validated goals to demonstrate the adequacy of the design, systems, structures, and components.

And when you're talking about major design choices at the construction permit stage like the absence of the physical containment, then it really highlights the risk that the applicant can gain by going forward at this point with those design choices that may be non-conservative, that may be shown to be non-conservative once the operating license application is submitted and some of this data is provided.

And again, it raises serious doubts in my mind whether the staff would be able to have the conviction to impose major retrofits to the approved construction permit design based on the outcome of these studies that are to be determined, and so, again, it doesn't seem --

Especially with an LMP-based approach to design and the fact that major design choices that will be difficult or impossible to make changes to later if the data warrants it, it just doesn't seem credible that there would be an effort to try to fix that problem at the operating license stage, and so I continue to be very concerned about the way all of this is unfolding. Thank you.

CHAIR ROBERTS: Okay, thank you, Dr. Lyman. Okay, is there anybody else online or in the room that would like to make a comment? Okay, seeing None, the next step in the agenda is the committee discussion.

We would have a somewhat incomplete discussion without having heard the closed part, but I think we can make some general conclusions. I guess, Bob, I'll turn to you first. Do you see any need for us to write a letter report on the DBA with no release topical report?

MEMBER MARTIN: Coming into this meeting, my feeling was that I could capture probably some insights in the summary report. I still kind of feel that way.

One alternative might be, given that we're looking at four different topical reports between today and tomorrow, maybe collectively we do one, and we can make a decision on that maybe at the end of tomorrow, but at this point, I don't think I saw anything in the presentations that I didn't already capture in my earlier review.

CHAIR ROBERTS: Okay, any other discussion on that? I kind of agree with you, Bob. I think Matt put it out at the end of this first session. This is a methodology with a lot of TBDs yet to come, which raises a question about the appropriateness of the TBDs and where this cutoff is for the construction permit application.

I think that would be a great discussion point as we review the CP coming up in the fall, that the staff, I'm sure, will come to us with some of Reed's judgments, with a little more background on what is the basis for a judgment that this is good enough for the CP.

That's a very important question to come through, but in terms of what we heard today, I think we heard a methodology that has a lot of TBDs and it follows a reg guide, and I'm not sure we heard anything that would cause us concern at this point.

MEMBER MARTIN: The catchall limitation and condition, number two, covers a lot of the concerns, so past that point, it's relatively complete.

CHAIR ROBERTS: I agree with you. We can certainly have this discussion again if we hear from the staff on the other two topical reports tomorrow.

MEMBER HALNON: This is Greg. The only counter I would do on that is taking in Dr. Lyman's comment that we're satisfied because we see a lot behind the scenes information.

If we do a summary report, not putting proprietary information into it, but we should at least acknowledge the fact that we've looked at a lot of proprietary information, and when you couple it all up, it looks good to us, if that's the case, as opposed to not even listening to what he said. I think it's important. There is a lot of proprietary information in there.

MEMBER MARTIN: I can certainly go both ways. I think if we're going to do a letter, we do the four, the four topicals that capture the details, plus any additional, but we could do it in the summary report, either way.

MEMBER PETTI: We haven't gotten into it, but I definitely think, well, we always write one for new technology. This is the first sodium, and now we got enough to draft something that's 200 lines, so.

CHAIR ROBERTS: Yeah, Bob, we can revisit this tomorrow, but my inclination is unless we hear something in the closed session, I think focusing the letter on the source term, if that's where we end up, would be a cleaner letter than tying in the other three topicals that really don't have anything to offer at this point. Scott, do you have any thoughts on the stability report?

MEMBER PALMTAG: Yeah, I don't think a letter is necessary. I mean, I kind of went into this from the physics point of view not expecting stability to be a big deal, and I think their analysis confirmed that, so I don't see any issues.

MEMBER PETTI: I just think this idea that -- this question is going to come again. How much do you need for a CP in terms of methods and how far along the path? Whatever summary we put together, we ought to capture that as sort of a finding because I don't think that -- that's not enough to write a letter, but it's there so that NRC management and people that read our summaries can see that, because I think it's important.

I mean, Josh is listening. Management has it, but, you know, it's for his bosses and stuff. We think that's an important thing, a consideration across the applications that are coming down the pike.

MEMBER PALMTAG: Yeah, well, we struggled with that obviously.

MEMBER PETTI: Right, and I even think, I mean, we could have a whole discussion with the staff about, okay, if you're a test reactor, here's the bar. If you're a CP test reactor, a CP operating reactor -- I end up having to explain this a lot to people who do not understand the nuances and the burden of proof differences that are out there.

CHAIR ROBERTS: Okay, any further discussion at this point? So, we have coming up the closed meeting on both of these two topical reports. The public schedule says after the open meeting. Right now, it's 11:20 Eastern, so I think we could get started at 12:30.

Is there anything wrong with that, Larry or Kent? Yeah, so let's go ahead and recess for lunch until 12:30 Eastern Time, and then we'll come back and start with the applicant, a closed presentation on the DBA topical report. And with that, we're in recess until 12:30 Eastern.

(Whereupon, the above-entitled matter went off the record at 11:21 a.m.)

March 05, 2025

TP-LIC-LET-0400
Docket Number 50-613

U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
ATTN: Document Control Desk

Subject: Submittal of Presentation Materials for March 2025 Natrium Design Advisory Committee on Reactor Safeguards Subcommittee Meeting

This letter transmits the TerraPower, LLC (TerraPower) presentation material for the upcoming March 18th and 19th 2025 Advisory Committee on Reactor Safeguards Subcommittee meetings (Enclosures 2, 3, 4, 5, 10, 11, 12, and 13).

The presentation material contains proprietary information and as such, it is requested that Enclosures 10, 11, 12, and 13 be withheld from public disclosure in accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding." An affidavit certifying the basis for the request to withhold Enclosures 10, 11, 12, and 13 from public disclosure is included as Enclosure 1. Enclosure 10 also contains ECI which can only be disclosed to Foreign Nationals in accordance with the requirements of 15 CFR 730 and 10 CFR 810, as applicable. Proprietary and ECI materials have been redacted from the presentation material provided in Enclosures 6, 7, 8, and 9; redacted information is identified using [[ ]]$^{(a)(4)}$, [[ ]]^{ECI}, or [[ ]]$^{(a)(4), ECI}$.

This letter and enclosures make no new or revised regulatory commitments.

If you have any questions regarding this submittal, please contact Ian Gifford at igifford@terrapower.com.

Sincerely,

George Wilson

George Wilson
Senior Vice President, Regulatory Affairs
TerraPower, LLC

Enclosures:
1. TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure (10 CFR 2.390(a)(4))
2. "Natrium Stability Methodology" Presentation Material – Open Meeting – Non-Proprietary (Public)
3. "DBA Methodology for In-Vessel Events without Radiological Release" Presentation Material – Open Meeting – Non-Proprietary (Public)
4. "Mechanistic Source Term Methodology" Presentation Material – Open Meeting – Non-Proprietary (Public)
5. "Radiological Release Consequences Methodology" Presentation Material – Open Meeting – Non-Proprietary (Public)
6. "Natrium Stability Methodology" Presentation Material – Closed Meeting – Non-Proprietary (Public)
7. "DBA Methodology for In-Vessel Events without Radiological Release" Presentation Material – Closed Meeting – Non-Proprietary (Public)
8. "Mechanistic Source Term Methodology" Presentation Material – Closed Meeting – Non-Proprietary (Public)
9. "Radiological Release Consequences Methodology" Presentation Material – Closed Meeting – Non-Proprietary (Public)
10. "Natrium Stability Methodology" Presentation Material – Closed Meeting – Proprietary and Export-Controlled (Non-Public)
11. "DBA Methodology for In-Vessel Events without Radiological Release" Presentation Material – Closed Meeting – Proprietary (Non-Public)
12. "Mechanistic Source Term Methodology" Presentation Material – Closed Meeting – Proprietary (Non-Public)

13. "Radiological Release Consequences Methodology" Presentation Material – Closed Meeting – Proprietary (Non-Public)

cc: Mallecia Sutton, NRC
Josh Borromeo, NRC
Nathan Howard, DOE
Jeff Ciocco, DOE

ENCLOSURE 1

TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure (10 CFR 2.390(a)(4))

Enclosure 1
TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure
(10 CFR 2.390(a)(4))

I, George Wilson, hereby state:

1. I am the Senior Vice President, Regulatory Affairs and I have been authorized by TerraPower, LLC (TerraPower) to review information sought to be withheld from public disclosure in connection with the development, testing, licensing, and deployment of the Natrium® reactor and its associated fuel, structures, systems, and components, and to apply for its withholding from public disclosure on behalf of TerraPower.
2. The information sought to be withheld, in its entirety, is contained in Enclosures 10, 11, 12, and 13, which accompany this Affidavit.
3. I am making this request for withholding, and executing this Affidavit as required by 10 CFR 2.390(b)(1).
4. I have personal knowledge of the criteria and procedures utilized by TerraPower in designating information as a trade secret, privileged, or as confidential commercial or financial information that would be protected from public disclosure under 10 CFR 2.390(a)(4).
5. The information contained in Enclosures 10, 11, 12, and 13 accompanying this Affidavit contains non-public details of the TerraPower regulatory and developmental strategies intended to support NRC staff review.
6. Pursuant to 10 CFR 2.390(b)(4), the following is furnished for consideration by the Commission in determining whether the information in Enclosures 10, 11, 12, and 13 should be withheld:
   a. The information has been held in confidence by TerraPower.
   b. The information is of a type customarily held in confidence by TerraPower and not customarily disclosed to the public. TerraPower has a rational basis for determining the types of information that it customarily holds in confidence and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application and substance of that system constitute TerraPower policy and provide the rational basis required.
   c. The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR 2.390, it is received in confidence by the Commission.
   d. This information is not available in public sources.
   e. TerraPower asserts that public disclosure of this non-public information is likely to cause substantial harm to the competitive position of TerraPower, because it would enhance the ability of competitors to provide similar products and services by reducing their expenditure of resources using similar project methods, equipment, testing approach, contractors, or licensing approaches.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on: March 05, 2025

George Wilson

George Wilson
Senior Vice President, Regulatory Affairs
TerraPower, LLC

ENCLOSURE 2

“Natrium Stability Methodology”
Presentation Material – Open Meeting

Non-Proprietary (Public)

Natrium Stability Methodology

Natrium Design ACRS Subcommittee Meeting

March 2025

TerraPower

Natrium

TP-LIC-PRSNT-0042

Natrium reactor is a TerraPower & GE Hitachi technology

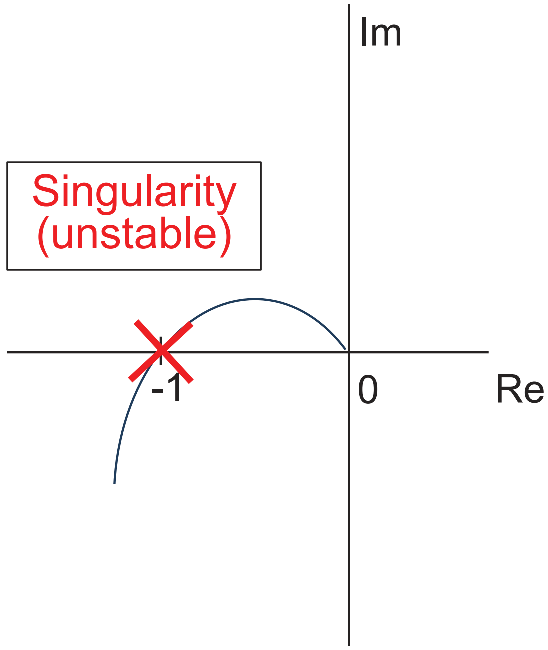
Topical Report Purpose

- Provide a description of the methodology developed to characterize Natrium Sodium-cooled Fast Reactor (SFR) stability
- We are seeking to leverage the methodology in subsequent licensing interactions, subject to the Limitations specified

Methodology Overview

Regulatory Requirement and Figure of Merit

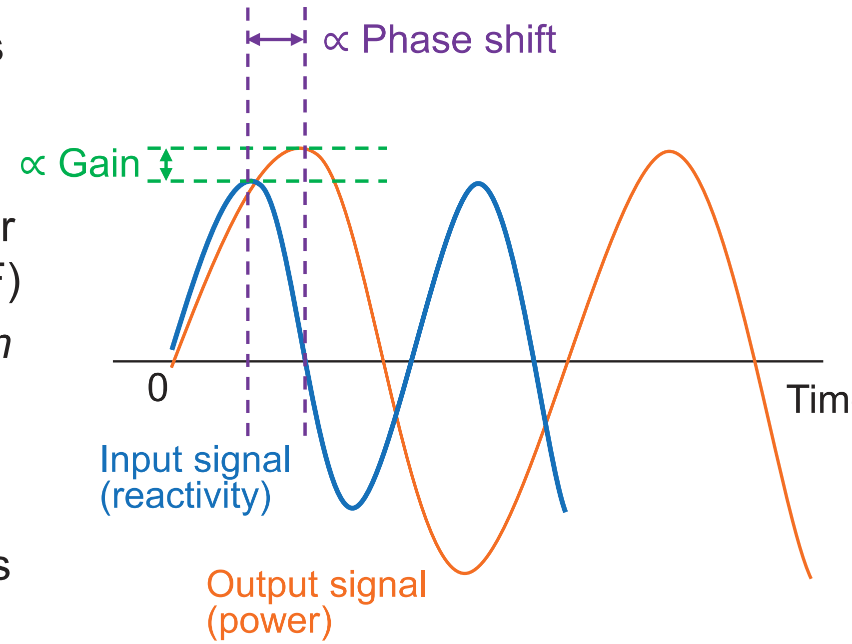
- Natrium Principal Design Criterion (PDC) 12 states:
  - The reactor core; associated structures; and associated coolant, control, and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable radionuclide release design limits [SARRDLs] are not possible or can be reliably detected and suppressed.
- The methodology will be used to demonstrate that power oscillations with a potential to exceed SARRDLs are not possible
- Nyquist stability criterion is the figure-of-merit (FOM) used to assess the stability of the system
  - FOM defines the system as unstable when the open loop transfer function (OLTF) encircles or passes through the -1+0j point on the complex plane (also known as the singularity location)



Methodology Overview

Overall Evaluation Approach

- Goal: Sample the range of inputs to ensure Natrium reactor stability over all anticipated conditions
  - With Nyquist as the FOM, the methodology thus yields a set of Nyquist results characterizing all anticipated conditions on a stability map
- OLTF consists of two components: the zero power transfer function (ZPTF) and the full power transfer function (FPTF)
  - ZPTF is a measure of the reactor power response *gain* and *phase shift* relative to a sinusoidal input reactivity signal in the **absence** of reactivity feedback effects
  - FPTF is the *gain* and *phase shift* of power relative to reactivity in the **presence** of reactivity feedback effects



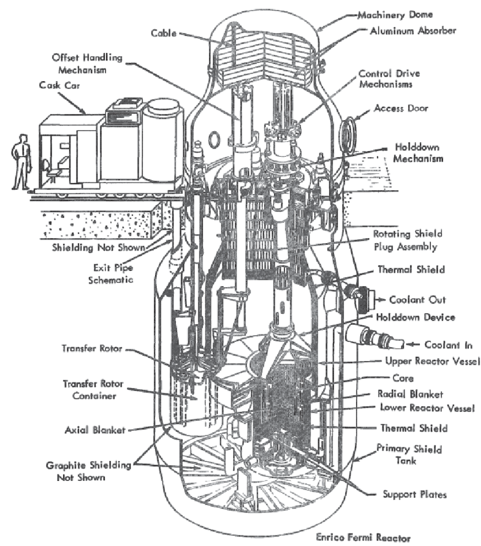
Methodology Overview

Benchmark: Fermi-1 Oscillator Rod Measurements

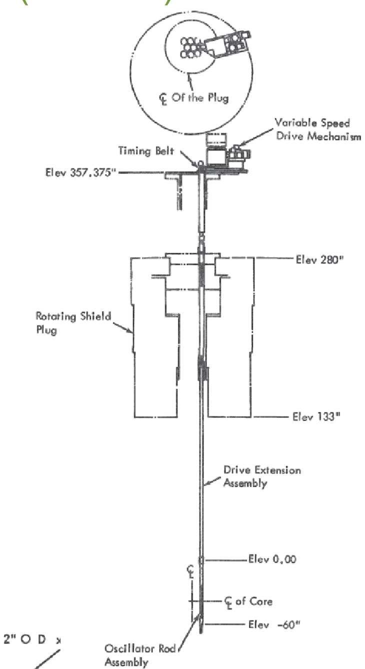
Images reference: A. Klickman et. al., "Oscillator Tests in the Enrico Fermi Reactor," Atomic Power Development Associates, Inc., APDA-NTS-11, 1967.

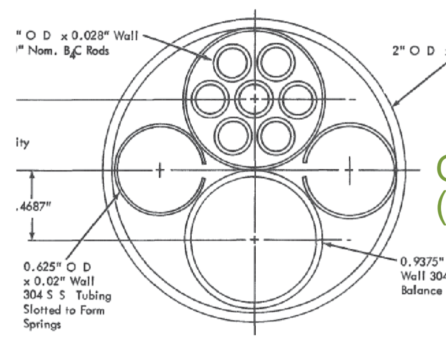
- Fermi-1 was a commercial power reactor (1960s)
  - Similar to Natrium reactor: Metal fuel, sodium coolant, fast spectrum, several hundred Megawatt power level
- Oscillator rod measurements performed during startup testing of the facility
  - Applied a sinusoidal reactivity input at frequencies from 5 Hz to 5e-3 Hz
  - ZPTF and FPTF directly measured
- Natrium stability methodology evaluated with this benchmark
  - Showed good agreement once Fermi-1-specific model refinements were applied

Reactor vessel



Oscillator rod (YZ view)





Oscillator rod (XY view)

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Methodology Overview

TerraPower-Identified Limitations (Paraphrased)

- Limitation 1 discusses how inputs provided to the methodology calculated by other methodologies are to capture the higher-fidelity behavior of the identified important phenomena in a manner consistent with their incorporation into this methodology.
- Limitation 2 generally directs that the specific application of model uncertainties must be reviewed and approved by the NRC.

Conclusions

- A methodology for stability evaluations of the Natrium reactor to demonstrate satisfaction of PDC 12 has been developed
- The methodology is designed to perform stability evaluations over the entire anticipated operating domain
- The methodology was evaluated with a benchmark application to Fermi-1, which showed good agreement once Fermi-1-specific model refinements were applied
- Two Limitations define restrictions on the methodology’s future application


Questions?

Acronym List

FOM – Figure-of-Merit
FPTF – Full Power Transfer Function
OLTF – Open Loop Transfer Function
PDC – Principal Design Criteria
SARRDL – Specified Acceptable System Radionuclide Release Design Limit
SFR – Sodium Fast Reactor
ZPTF – Zero Power Transfer Function

ENCLOSURE 3

"DBA Methodology for In-Vessel Events without Radiological Release"
Presentation Material – Open Meeting

Non-Proprietary (Public)

DBA Methodology for In-Vessel Events w/o Radiological Release

Natrium Design ACRS Subcommittee Meeting

March 2025

TerraPower

Natrium

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

TP-LIC-PRSNT-0032

Natrium reactor is a TerraPower & GE Hitachi technology

Objectives

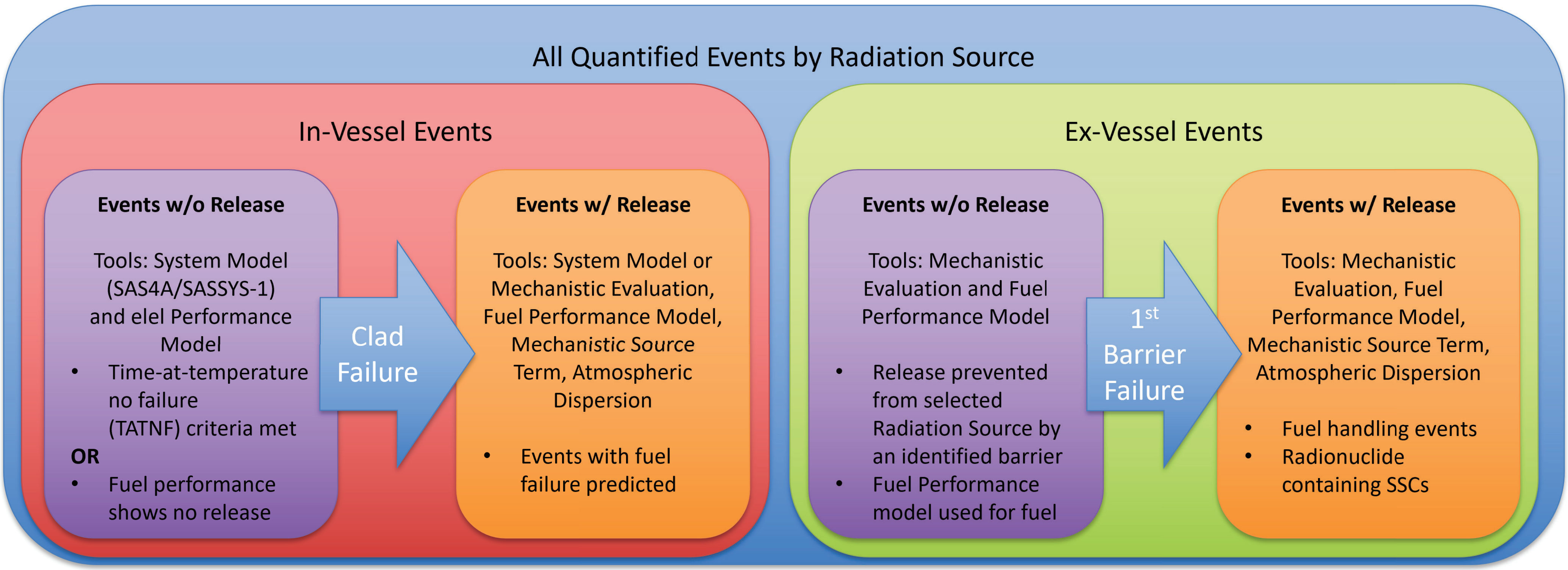
- Provide a general summary of the evaluation model for in-vessel design basis accident (DBA) events that did not result in a release (i.e. event scenarios where the reactor shuts down and the fuel cladding remains intact).

- The current topical report is intended to support the Preliminary Safety Analysis Report (PSAR) as part of the Construction Permit Application (CPA). Further development is still ongoing to complete all the steps in the Evaluation Model Development and Assessment Process (EMDAP) to support Final Safety Analysis Report (FSAR) as part of the Operation License Application (OLA).

Contents of the Topical Report

- Definition of the event parameters in scope of the methodology
- Development of the Natrium evaluation model (EM)
    - Requirements for EM development
    - Development of Assessment Base
    - EM development
    - Assessment of EM Adequacy
- Adequacy Decision
- Conclusions and Limitations

In-Vessel DBAs without Radiological Release



In-Vessel DBAs without Radiological Release

- From design basis events (DBEs) as defined in NEI 18-04
- Representative in-vessel DBAs without radiological release for Phenomena Identification and Ranking Table (PIRT) development
    - Loss Of Offsite Power (LOOP)
    - Loss Of Heat Sink (LOHS)
    - Rod Withdrawal At Power (RWAP)

Requirements for EM Development

- Using guidance of RG 1.203 and NUREG-1737 to achieve compliance with RG 1.203 Regulatory Position 1 using an ISTIR-based methodology
- EM capability requirements – EMDAP Element 1 (Steps 1-4): to determine the exact envelope for the EM, and to identify and agree upon the importance of the constituent phenomena, processes, and key parameters.
  1. Analysis purpose
     - To demonstrate that the plant operations are in compliance with the GDC under normal operational conditions and during in-vessel DBAs without radiological release

Requirements for EM Development

- EM capability requirements – EMDAP Element 1 (Steps 1-4)

2. Figures of Merit
   - Fuel Centerline Temperature
   - Coolant Temperature
   - Time-at-Temperature for Peak Cladding Temperature
3. Identification of Natrium systems, components, phases, geometries, fields, and processes
4. Development of PIRTs following the guidance given in NUREG/CR-6944
   - One representative PIRT combined conservatively from five individual PIRTs

Development of Assessment Base

- EM assessment base development – EMDAP Element 2 (Steps 5-9): development of scaling methodology that includes acquiring experimental data relevant to the scenarios being considered and ensuring the suitability of experimental scaling

5. Assessment base objectives
    - Selection/creation of IET facilities & possible plant transient data complemented by SET necessary to provide sufficient experimental data to assure adequate assessment of EM

Development of Assessment Base

- EM assessment base development – EMDAP Element 2 (Steps 5-9)

6. Scaling analysis and similarity criteria
   - Hierarchical Two-Tiered Scaling (H2TS) & Similarity criteria for a closed forced/natural circulation flow loop
7. EM assessment matrix development
   - Consists of TerraPower and legacy tests – IETs and SETs
8. Evaluation of IET distortions and SET scaleup capability
   - To be performed
9. Experimental uncertainties determination
   - To be performed in compliance with the QA requirements

EM Development

- Evaluation model development – EMDAP Element 3 (Steps 10-12): Satisfaction of requirements identified in Element 1

10. EM development plan: specification of standards & procedures to achieve satisfaction of Regulatory Positions 2 and 3 of RG1.203
11. EM structure: SAS4A/SASSYS-1 (SAS) is the basis of EM.
12. Closure models and conservatisms
    - Three new closure correlations have been implemented in SAS.
    - Inserting conservative biases on the nominal inputs & applying conservative model assumptions and model options
    - Safety-related (SR) structures, systems, and components (SSCs) only (requirement)

Assessment of EM Adequacy

- Evaluation model adequacy assessment – EMDAP Element 4 (Steps 13-20): assess top-down/bottom-up pedigree, fidelity, and scalability to achieve compliance with Principle #4 discussed on page 4 in RG 1.203

  13. to 15. Evaluation of closure relations – Bottom-up (To be performed)

  - Determine pedigree and applicability
  - Assess model fidelity and accuracy
  - Assess scalability of models

Assessment of EM Adequacy

- Evaluation model adequacy assessment – EMDAP Element 4 (Steps 13 – 20)

16. to 19. Evaluation of integrated EM – Top-down (To be performed)

  - Determine capabilities of field equations and numeric solutions,
  - Determine applicability to simulate system components,
  - Assess system interactions and global capability,
  - Assess scalability of integrated calculations and data for distortions

20. Determine EM biases and uncertainties – To be performed

Adequacy Decision

- Establishment of standard questions concerning EM adequacy
- Answering adequacy questions
- Completion of EM development when all adequacy questions are satisfactory, and validation results are acceptable.
- To be performed

Conclusions and Limitations

- Conclusion
  - Methodology proposed aligns with regulatory guidance.
- Self-imposed Limitations
  - The methodology is limited to a Natrium design that has a pool-type, SFR design with metal fuel.
  - Adequate verification and validation assessment information should be made available to the NRC staff as part of future submittals supporting the codes that make up the EM.
  - An applicant utilizing the topical report needs to justify the use of the model for the design, including discussions of the capability of the model.


Questions?

Acronym List

CPA – Construction Permit Application
DBA – Design Basis Accident
DBE – Design Basis Event
EM – Evaluation Model
EMDAP – Evaluation Model Development and Assessment Process
FSAR – Final Safety Analysis Report
GDC -- General Design Criteria
H2TS – Hierarchical Two-Tiered Step
IET – Integral Effects Test
ISTIR – Integrated Structure for Technical Issue Resolution
LOOP – Loss Of Offsite Power
LOHS – Loss Of Heat Sink
NEI – Nuclear Energy Institute
PIRT – Phenomena Identification and Ranking Table
PSAR – Preliminary Safety Analysis Report
OLA – Operation License Application
QA -- Quality Assurance
RG – Regulatory Guide
RWAP – Rod Withdrawal At Power
SAS – SAS4A/SASSYS-1
SET – Separate Effects Test
SFR – Sodium-cooled Fast Reactor
SR – Safety Related
SSC – Structures, Systems, and Components
TATNF – Time-at-Temperature No Failure

ENCLOSURE 4

"Mechanistic Source Term Methodology"
Presentation Material – Open Meeting

Non-Proprietary (Public)

Mechanistic Source Term Methodology

Natrium Design ACRS Subcommittee Meeting

March 2025

TerraPower

Natrium.

TP-LIC-PRSNT-0043

Natrium reactor is a TerraPower & GE Hitachi technology

Source Term Evaluation Model (EM)

Purpose & Objective

- Topical report NAT-9392 describes the development of a mechanistic source term evaluation model utilized for the Natrium CPA
- The objective of the source term is to provide input for evaluating the radiological consequences of quantified events
- Certain aspects of the EM remain in development and are noted in the topical report
- It is acknowledged that information from ongoing and future development actions will be completed prior to use of the EM in an OLA

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Source Term Evaluation Model (EM)

Introduction

- EM development generally adheres to RG 1.203 insofar as applicable to the Natrium design and is coupled with TerraPower methodology development guidance
- EMDAP Process – 4 Elements with 20 Steps
  - Element 1 – Establish Requirements for EM Capability
  - Element 2 – Develop Assessment Base
  - Element 3 – Develop EM
  - Element 4 – Assess EM Adequacy

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Source Term Evaluation Model (EM)

Intended Natrium Applications

- Normal Operation
- System Leakage Scenarios
- Licensing Basis Events (LBE) and OQEs
  - LBEs include AOO, DBE, DBA, BDBE
- Emergency Planning Zone (EPZ) Sizing
- Dose Mapping for EQ Evaluations

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

EM Capability Requirements

Element 1 - Defines the Source Term EM Capabilities

- Apply to all transient classes that can result in fuel failure
- PIRT to identify and rank key phenomena
  - Performed for 3 representative events
- Figures of Merit
  - Inhalation dose potential
  - Submersion dose potential

Functional Containment

Definitions and Establishment

- Adopt Functional Containment definition from SECY-18-0096:
  Barrier or set of barriers that effectively limits transport of radioactive material to environment.
- Barrier Type Defined by Function
  - Primary – SSC that performs radionuclide retention function necessary to keep offsite DBA doses within regulatory limits or keep DBE consequences from exceeding F-C targets.
  - Enveloping – SSC that provides a backup radionuclide retention function following failure or breach of an associated primary barrier.
- Establishes performance criteria for the barrier types

EM Assessment Base

Element 2 - Objectives

- Evaluated existing tests, benchmarks, simple test problems and any plant transient data
- Developed PIRT for Selected Scenarios
- Ranking Phenomenon/Processes Completed

EM Assessment Base

Element 2 - Scaling, Distortions, Uncertainty

- Some scaling analysis has been performed
- Qualification efforts for experimental work related to uncertainty arising from measurement errors and experimental distortions
- Conservative approaches outlined if experimental data lacking

EM Development

Element 3 - EM Development Plan

- The EM consists of a group of software codes
  - Output from upstream software codes and EMs (e.g., Fuel Failure with Release EM, etc.) used as input to Source Term EM
  - Output from Source Term EM used as input for Radiological Consequences EM
- Life Cycle and V&V plans developed for Source Term software codes
- Software code capability gaps identified with plans developed to fill the gaps

EM Development

Element 3 - EM Structure & Closure Models

- Structure of individual software codes defined for six ingredients listed in RG 1.203
  - Systems and components, constituent phases, field equations, closure relations, numerics, and additional features
- Develops and defines interfaces with other EMs
- Models incorporated for pool scrubbing and aerosol natural deposition

EM Development

Element 3 - Modeling Strategies

- Sodium chemical reaction modeling
- EM determines dose significant radionuclides for input into calculational devices
- Functional containment
  - Compartment conditions
  - Determine barrier leakage rates
- Radionuclide transport and mitigation phenomena

EM Adequacy Assessment

Element 4 - Assessments of Models

- Capability of equations/solutions to represent processes
- Simulate system components
- Code verifications conducted for software codes used
- Code validations ongoing with some software codes
- Strategy for gaps has been outlined
- Model prediction biases and uncertainties to be developed as necessary

EM Adequacy Assessment

Element 4 - Comparison & Identification

- Natrium methodology compared to RG 1.183 Regulatory Positions 2.1 to 2.5
- Identified potential source list and releases (types, end points)
- Code identification/evaluation for source term release modeling
- Code verification against model fidelity and accuracy
- Work is ongoing in this area

Interface with Other EMs

Handoff to Radiological Consequences EM

- Source Term EM output are time dependent matrices of radionuclide inventory released to the environment
- Format and periodicity of the output may be event and software dependent
- Data is transferred via controlled electronic files to Radiological Consequences EM for each event
- Topical Report contains two sample calculations demonstrating application of Source Term EM


Questions?

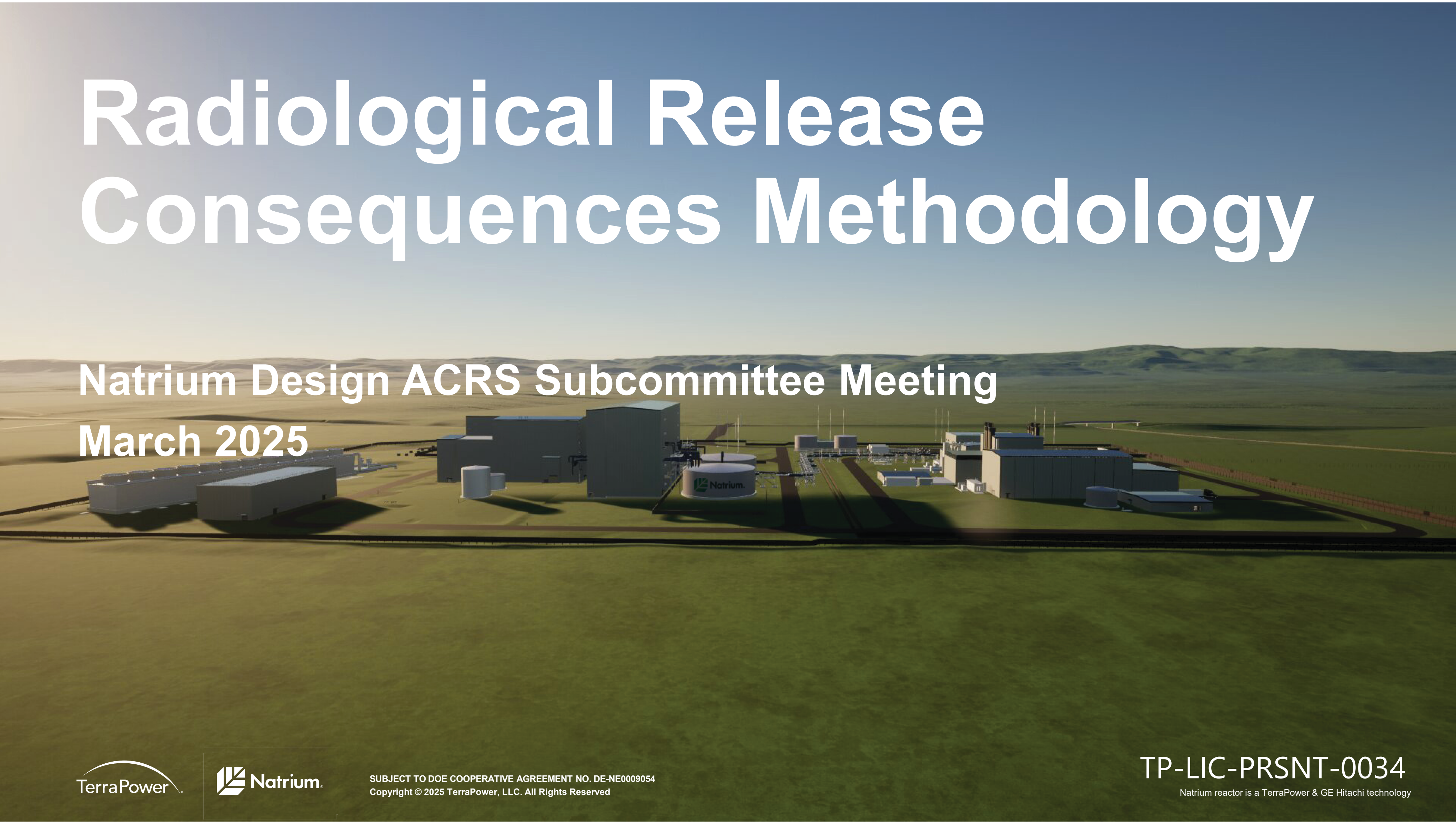
Acronym List

ACRS – Advisory Committee on Reactor Safeguards
AOO – Anticipated Operational Occurrence
BDBE – Beyond Design Basis Event
CPA – Construction Permit Application
DBA – Design Basis Accident
DBE – Design Basis Event
EM – Evaluation Model
EMDAP – Evaluation Model Development and Assessment Process
EPZ – Emergency Planning Zone
EQ – Equipment Qualification
F-C – Frequency-Consequence
IET – Integrated Effects Testing
LBE – Licensing Basis Event
OLA – Operating License Application
OQE – Other Quantified Events
PIRT – Phenomena Identification and Ranking Table
RG – Regulatory Guide
SSC – Structures, Systems, and Components
V&V – Verification and Validation

ENCLOSURE 5

"Radiological Release Consequences Methodology"
Presentation Material – Open Meeting

Non-Proprietary (Public)



Radiological Release Consequences Methodology

Natrium Design ACRS Subcommittee Meeting

March 2025

TerraPower

Natrium

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

TP-LIC-PRSNT-0034

Natrium reactor is a TerraPower & GE Hitachi technology

Table of Contents

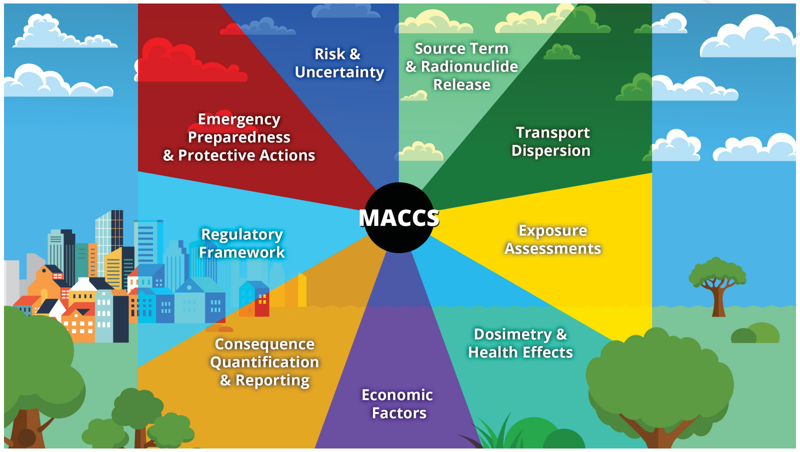
NAT-9391 – LBE EM

Methodology Objectives

- Objective is to determine the following radiological consequences:
  1. 30-day Total Effective Dose Equivalent (TEDE) at the Exclusion Area Boundary (EAB)
  2. Probability of exceeding 100 mrem 30-day TEDE at the site boundary
  3. Risk of early fatality within 1 mile of the EAB
  4. Risk of latent cancer fatality within 10 miles of the EAB
- The inhalation, submersion, and groundshine dose pathways are considered
- Consequence #1 is used to generate the F-C Target
- Consequences #2-#4 are used to generate the quantitative health objectives

NAT-9391 – LBE EM

Methodology Overview



- Consequences are determined probabilistically using the WinMACCS code, referred to as MACCS
- MACCS input guidance includes:
  - NUREG-1150, "*Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants*"
  - NUREG-1935, "*State-of-the-Art Reactor Consequence Analyses (SOARCA) Report*"
  - NUREG/CR-7270, "*Technical Bases for Consequence Analyses Using MACCS (MELCOR Accident Consequence Code System)*"

NAT-9391 – LBE EM

Uncertainty Treatment

- Due to the large number of MACCS inputs, sensitivity studies are first used to determine which uncertain parameters require explicit treatment
- Two uncertainty treatments are outlined:
    1. Deterministic - Applying a conservative value which bounds parameter uncertainty (always used in DBA and CRH EMs)
    2. Probabilistic - Randomly sampling parameter values from a representative distribution, computing consequences, and extracting 5th percentile, mean, and 95th percentile results from the distribution of results (always used in LBE EM for weather uncertainty)

NAT-9391 – LBE EM

Significant Changes Following NRC Review

- Use of the CHRONC module of the MACCS code was added to account for contributions to latent cancer fatality risk that occur in the 50 years following an event
  - Without use of the CHRONC module, consequences were determined after 30 days
  - Dose pathways within the CHRONC module are resuspension inhalation and groundshine
- Use of Federal Guidance Report (FGR) 11 and 12 Dose Conversion Factors (DCFs) to calculate TEDE

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

NAT-9391 – LBE EM

EPZ Radiological Consequences

- The Plume Exposure Pathway (PEP) EPZ sizing methodology is established in NAT-3056
- Two radiological consequences are considered:
  - 96-hour TEDE at the PEP EPZ boundary
  - 24-hour acute red bone marrow dose at PEP EPZ boundary
- Can be calculated using LBE EM with two changes:
  - Reduction of duration to 96 or 24 hours
  - Output of TEDE or acute red bone marrow dose at PEP EPZ boundary

NAT-9391 – DBA EM

Methodology Objectives and Overview

- Objective is to determine the following dose consequences:
  - The highest TEDE received over any 2-hour period at the EAB
  - The 30-day TEDE received at the low population zone
- Inhalation and submersion dose pathways are considered
- The regulatory limit of 2-hour or 30-day TEDE is 25 rem
- Methodology aligns with applicable Regulatory Guide (RG) 1.183 Revision 1 guidance using an internally developed code

NAT-9391 – DBA EM

Released Radionuclide Consequence Analysis Tool (RRCAT)

- The RRCAT code models the release to the environment and resulting consequences similarly to the RADTRAD code
  - Atmospheric transport is modeled with undepleted atmospheric dispersion factors (χ/Q)
  - Offsite receptors are modeled as submerged in a semi-infinite plume
  - The control room is modeled as a single compartment exchanging air with a semi-infinite plume
- The RRCAT code accepts the source term release matrix as input while the RADTRAD code does not

NAT-9391 – CRH EM

Methodology Objectives and Overview

- Objective is to determine whether CRH is maintained from the 30-day TEDE
  - Submersion, inhalation, and shine dose pathways are considered
- The maximum permissible 30-day TEDE is 5 rem
  - Methodology aligns with applicable RG 1.183 Rev. 1 guidance using RRCAT

Questions?

Acronym List

CRH – Control Room Habitability
DBA – Design Basis Accident
DCF – Dose Conversion Factor
EAB – Exclusion Area Boundary
EM – Evaluation Model
EPZ – Emergency Planning Zone
F-C – Frequency-Consequence
FGR – Federal Guidance Report
LBE – Licensing Basis Event
MACCS – MELCOR Accident Consequence Code System
NRC – U.S. Nuclear Regulatory Commission
PEP – Plume Exposure Pathway
RG – Regulatory Guide
RRCAT – Released Radionuclide Consequence Analysis Tool
SOARCA – State-of-the-Art Reactor Consequence Analyses
TEDE – Total Effective Dose Equivalent

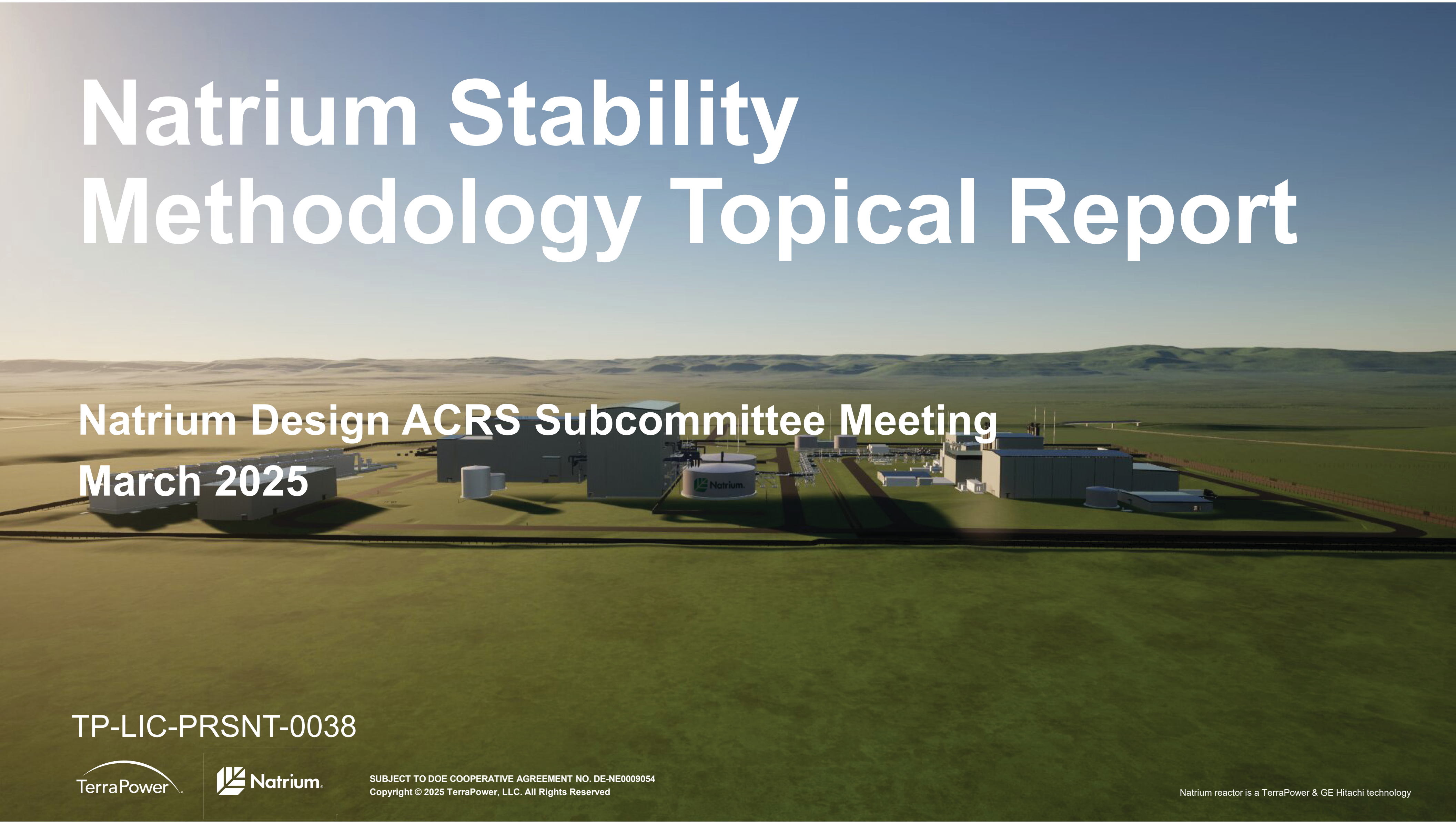
ENCLOSURE 6

“Natrium Stability Methodology”
Presentation Material – Closed Meeting

Non-Proprietary (Public)

Natrium Stability Methodology Topical Report

Natrium Design ACRS Subcommittee Meeting
March 2025



TP-LIC-PRSNT-0038

TerraPower Natrium

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Natrium reactor is a TerraPower & GE Hitachi technology

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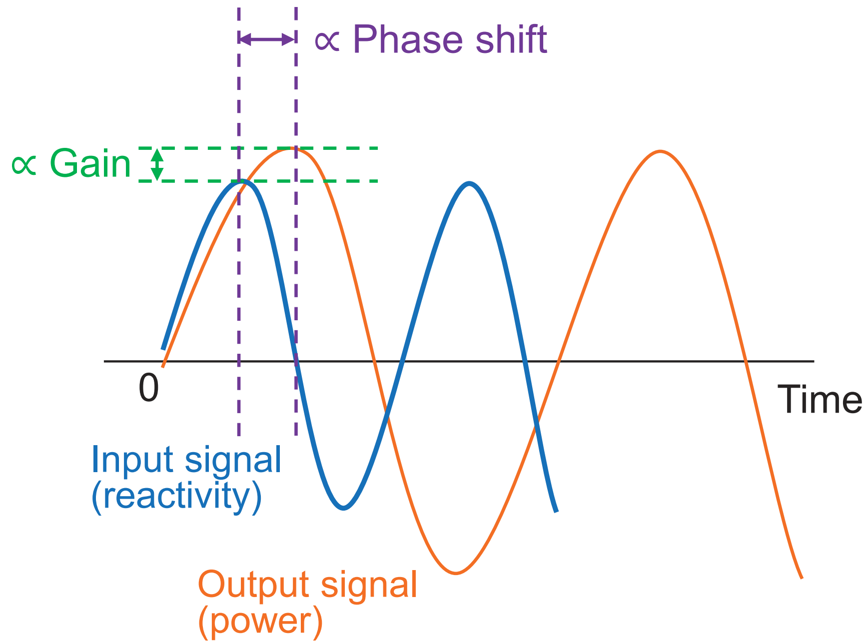
10 CFR 810, as applicable.

Portions of this presentation are considered proprietary and TerraPower, LLC requests it be withheld from public disclosure under the provisions of 10 CFR 2.390(a)(4).

Nonproprietary versions of this presentation indicate the redaction of such information using [[ ]]$^{(a)(4)}$, [[ ]]^{ECI}, or [[ ]]$^{(a)(4), ECI}$.

Methodology Overview
Stability Evaluation Model

- The Nyquist plot is the open loop transfer function (OLTF) plotted on the complex plane as a function of frequency (making it a frequency-domain result)
- OLTF consists of two components: the zero power transfer function (ZPTF) and the full power transfer function (FPTF)
  - ZPTF is a measure of the reactor power response *gain* and *phase shift* relative to a sinusoidal input reactivity signal in the **absence** of reactivity feedback effects
  - FPTF is the *gain* and *phase shift* of power relative to reactivity in the **presence** of reactivity feedback effects



Methodology Overview

Stability Evaluation Model

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Methodology Overview

Frequency Domain Treatment

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]](a)(4), ECI

Methodology Overview

Overall Evaluation Approach

- Goal: Sample the range of inputs to ensure Natrium stability over all anticipated conditions

[[

]](a)(4), ECI

- This yields a set of Nyquist results characterizing all anticipated conditions

Methodology Overview

Defining Stability Map

- The power and flow statepoints described previously encompass normal operation and AOOs to develop a Natrium stability map

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Methodology Overview
Uncertainties Treatment

- Two components: input uncertainties and model uncertainties
- Input uncertainties treatment

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- Model uncertainties treatment

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Methodology Overview

Input Uncertainties Treatment

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Methodology Overview

Model Uncertainties Treatment

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SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Methodology Overview

Uncertainties Treatment

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Methodology Overview

Uncertainties Treatment

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Methodology Overview

TerraPower-Identified Limitations

- Limitation 1:
  - Inputs provided to the methodology calculated by other methodologies are to capture the higher-fidelity behavior of the identified important phenomena in a manner consistent with their incorporation into this methodology.
- Limitation 2:
  - This topical report develops a [[ ]](a)(4) for the purpose of describing how such a [[ ]](a)(4) may be obtained and for the purpose of describing how such a [[ ]](a)(4) is subsequently applied as part of the methodology's calculation steps. In application, a [[ ]](a)(4) must be developed and appropriately justified for the use described in this methodology. Any applied [[ ]](a)(4) must be reviewed and approved by the NRC.

Conclusions

- A methodology for stability evaluations of the Natrium reactor to demonstrate satisfaction of PDC 12 has been developed
- The methodology is designed to perform stability evaluations over the entire anticipated operating domain
- The methodology was evaluated with a benchmark application to Fermi-1, which showed good agreement once Fermi-1-specific model refinements were applied
- Two Limitations define restrictions on the methodology’s future application


Questions?

Acronym List

AOO – Anticipated Operational Occurrence
BOL – Beginning of Life
CFR – Code of Federal Regulations
EOEC – End of Equilibrium Cycle
FPTF – Full Power Transfer Function
OLTF – Open Loop Transfer Function
PDC – Principal Design Criterion
ZPTF – Zero Power Transfer Function

ENCLOSURE 7

“DBA Methodology for In-Vessel Events without Radiological Release”
Presentation Material – Closed Meeting

Non-Proprietary (Public)

DBA Methodology for In-Vessel Events w/o Radiological Release

Natrium Design ACRS Subcommittee Meeting
March 2025

TP-LIC-PRSNT-0039

TerraPower Natrium

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Natrium reactor is a TerraPower & GE Hitachi technology

Portions of this presentation are considered proprietary and TerraPower, LLC requests it be withheld from public disclosure under the provisions of 10 CFR 2.390(a)(4).

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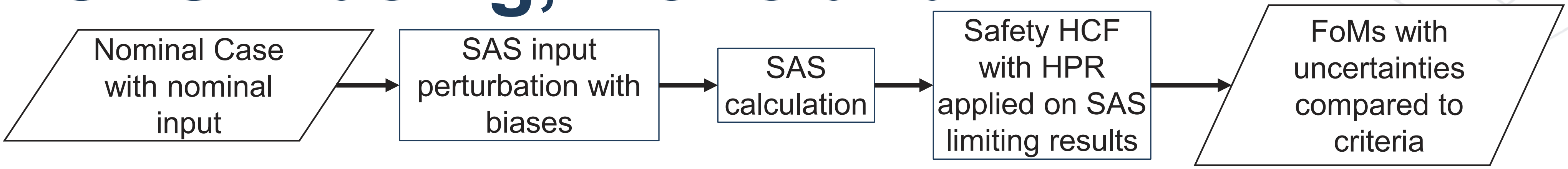
SAS Biasing, HCFs and HPR



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SAS Biasing, HCFs, and HPR (cont.)

Safety Hot Channel Factor

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SAS Biasing, HCFs, and HPR (cont.)

Hot Pin Ratio

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Questions?

Acronym List

DBA – Design Basis Accident
FOM – Figure-of-Merit
HCF – Hot Channel Factor
HPR – Hot Pin Ratio
SAS – SAS4A/SASSYS-1

ENCLOSURE 8

"Mechanistic Source Term Methodology"
Presentation Material – Closed Meeting

Non-Proprietary (Public)

Mechanistic Source Term Methodology

Natrium Design ACRS Subcommittee Meeting
March 2025

TP-LIC-PRSNT-0040

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Source Term Evaluation Model (EM)

Interface with other Natrium EMs

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Functional Containment

Definitions and Establishment

- SECY-18-0096: Barrier or set of barriers that effectively limits transport of radioactive material to environment
- Defines barrier type
  - Primary – SSC that performs radionuclide retention to keep offsite DBA doses within regulatory limits or keep DBE consequences from exceeding F-C targets
  - Enveloping – SSC that provides a backup radionuclide retention function
- Establishes performance criteria for the barrier types

Functional Containment Boundaries

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Interface with Other EMs

Handoff to Radiological Consequences EM

- Source Term EM output are time dependent matrices of radionuclide inventory released to the environment
- Format and periodicity of the output may be event and software dependent
- Data is transferred via controlled electronic files to Radiological Consequences EM for each event
- Topical Report contains two sample calculations demonstrating application of Source Term EM


Questions?

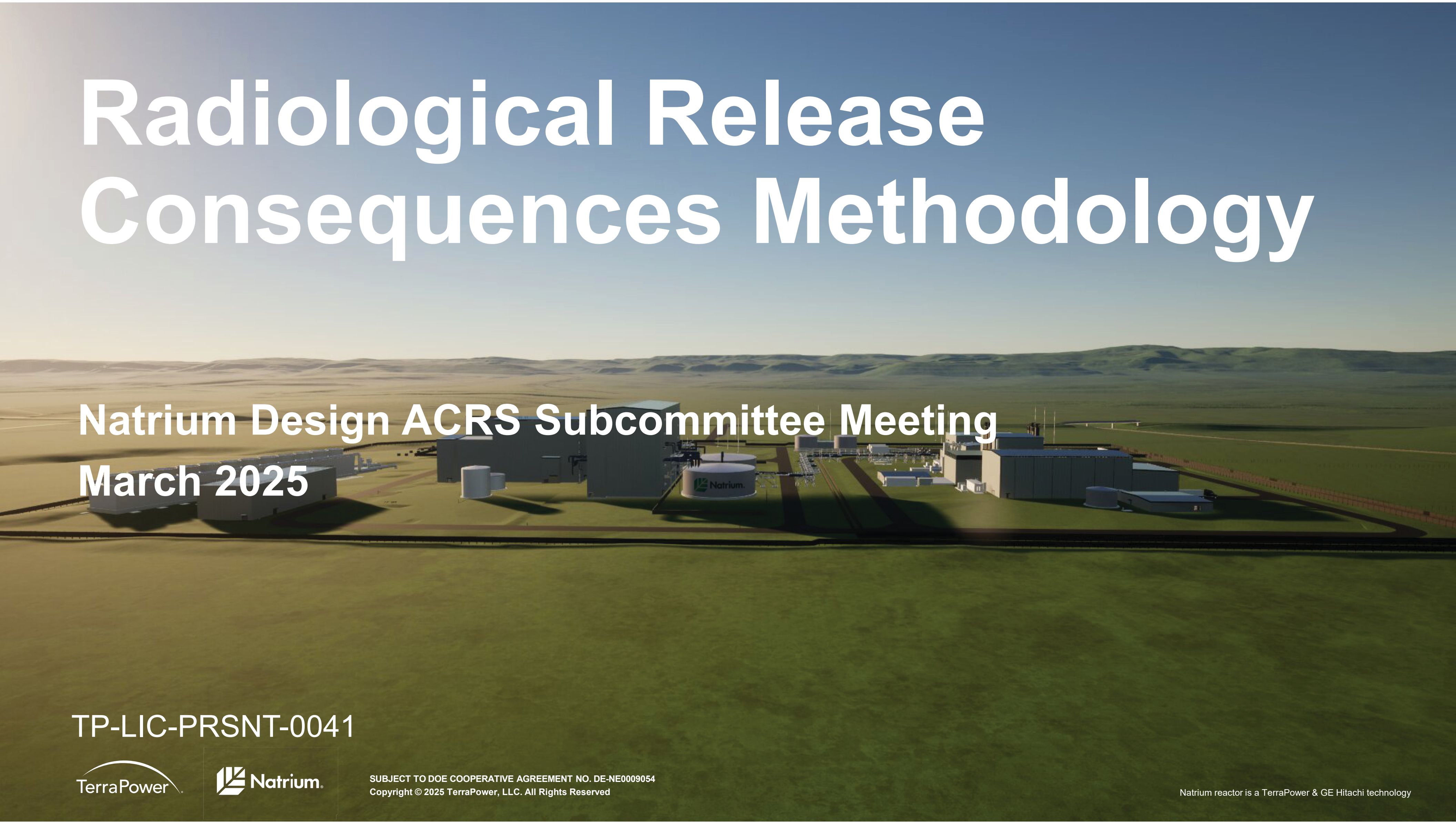
Acronym List

CATT – Core Assembly Transfer Tube
DBA – Design Basis Accident
DBE – Design Basis Event
DSAW – Detailed Safety Analysis Workflow
EM – Evaluation Model
EPZ – Emergency Planning Zone
EVHM – Ex-Vessel Handling Machine
F-C – Frequency-Consequence
FFV – Fueling Floor Valve
SSC – Structures, Systems, and Components
TATNF – Time-at-Temperature No-Failure

ENCLOSURE 9

“Radiological Release Consequences Methodology”
Presentation Material – Closed Meeting

Non-Proprietary (Public)



Radiological Release Consequences Methodology

Natrium Design ACRS Subcommittee Meeting
March 2025

TP-LIC-PRSNT-0041

TerraPower Natrium

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NAT-9391 – LBE EM

Methodology Objectives

- Objective is to determine the following radiological consequences:
    1. 30-day Total Effective Dose Equivalent (TEDE) at the Exclusion Area Boundary (EAB)
    2. Probability of exceeding 100 mrem 30-day TEDE at the site boundary
    3. Risk of early fatality within 1 mile of the EAB
    4. Risk of latent cancer fatality within 10 miles of the EAB
- The inhalation, submersion, and groundshine dose pathways are considered
- Consequence #1 is used to generate the F-C Target
- Consequences #2-4 are used to generate the quantitative health objectives

NAT-9391 – EM Flowchart

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NAT-9391 – LBE EM

Plume Model

- Source term release matrix may include hundreds of timesteps
  - Code input or runtime limitations may require consolidation
- [[

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- Ensures the release modeled in MACCS aligns with release matrix

NAT-9391 – LBE EM

Nuclide Selection

- Source term release matrix may include hundreds of nuclides
  - Code input or runtime limitations may require reduction
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NAT-9391 – CRH EM

Methodology Objectives and Overview

- Objective is to determine whether CRH is maintained from the 30-day TEDE
  - Submersion, inhalation, and shine dose pathways are considered
- The maximum permissible 30-day TEDE is 5 rem
- Methodology aligns with applicable RG 1.183 Rev. 1 guidance using the Released Radionuclide Consequence Analysis Tool (RRCAT)

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NAT-9391 – CRH EM

Shine Dose Conversion Factor (SDCF)

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Questions?

Acronym List

CRH – Control Room Habitability
DBA – Design Basis Accident
DCF – Dose Conversion Factor
DSAW – Detailed Safety Analysis Workflow
EAB – Exclusion Area Boundary
EM – Evaluation Model
EPZ – Emergency Planning Zone
F-C – Frequency-Consequence
LBE – Licensing Basis Event
LWR – Light Water Reactor
RG – Regulatory Guide
RRCAT – Released Radionuclide Consequence Analysis Tool
SDCF – Shine Dose Conversion Factor
TEDE – Total Effective Dose Equivalent

NRC Staff Review of the Topical Report "Reactor Stability Methodology," Revision 0

Roel Brusselmans, Project Manager

Reed Anzalone, Senior Nuclear Engineer

Office of Nuclear Reactor Regulation

Division of Advanced Reactors and
Non-Power Production and Utilization Facilities

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Agenda

- Review chronology
- Topical report (TR) purpose and review strategy
- Safety evaluation overview
- Conclusions
- Proposed Limitations and Conditions

Review Chronology

- June 29, 2023: Pre-Application Public Meeting (ML24012A067)
- November 23, 2023: Submittal of "Stability Methodology Topical Report," Revision 0 (ML23334A239)
- February 20, 2024: TR accepted for review by the NRC staff (ML23355A078)
- May through July 2024: Audit conducted (ML24233A292)
- August 16, 2024: Revision to the TR submitted (ML24232A231)
- January 31, 2025: NRC staff's draft safety evaluation issued (ML24324A218)

Related TerraPower submittal:

- March 28, 2024: TerraPower submitted, on behalf of US SFR Owner, LLC, a construction permit application for the Kemmerer Power Station Unit 1 (ML24088A059).

TR Purpose and Review Strategy

- Purpose of TR:
  - To describe the methodology used to characterize Natrium reactor stability. TerraPower states, "[n]uclear reactor stability analysis, as approached by this TR, is the study of a reactor's oscillatory power response to reactivity perturbations. Ensuring a stable (i.e., non-diverging) oscillatory reactor power response helps preclude controllability issues and limits the potential of failing to maintain design limits."
- Review strategy
  - Evaluate theoretical underpinning and prior uses of similar analytic methods
  - Evaluate treatment of uncertainties
  - Review demonstration of analytic methods and uncertainty treatment
  - Evaluate operating reactor benchmark

Safety Evaluation Overview

- Regulatory evaluation
- Summary of TR
- Technical evaluation
  - Operating domain and frequency domain
  - Uncertainty treatment
  - Fermi 1 benchmark evaluation
- Limitations and conditions
- Conclusions

Regulations and Review Scope

Principal Design Criterion 12: The reactor core; associated structures; and associated coolant, control and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable radionuclide release design limits (SARRDLs) are not possible or can be reliably and readily detected and suppressed.

- The TR provides methods to demonstrate that the Natrium reactor is stable in all conditions of normal operation, including anticipated operational occurrences.
- Detect and suppress solutions for unstable conditions are not within the scope of NRC staff review.

Relevant Natrium Design Features

- Pool-type sodium-cooled, fast reactor
  - Operates at near-atmospheric pressure
- Metallic fuel
  - Fuel is chemically compatible with coolant
  - Low fuel operating temperature gives substantial margin to coolant boiling
- Tightly coupled neutronic performance
  - Key reactivity phenomena act core-wide

Conclusions

The NRC staff concludes that the TR provides an acceptable methodology for assessing the stability characteristics of the Natrium reactor based on the following considerations:

1. The TR proposes an acceptable means to characterize and discretize the power-to-flow operating domain, including characteristics to indicate when a more detailed discretization would be necessary.
2. An applicant implementing the methodology will justify the selection of analyzed frequencies at each statepoint.
3. The TR methodology reflects a theoretical approach that has been used to evaluate stability in similar reactor system designs;
4. The TR methodology includes an acceptable means to characterize input and model uncertainty, and to justify these means; and
5. The TR includes an acceptable evaluation of a benchmarking exercise comparing its analytic methods to stability experiments in the Fermi 1 reactor.

Proposed Limitations and Conditions

1. Inputs provided to the methodology calculated by other methodologies are to capture the higher-fidelity behavior of the identified important phenomena in a manner consistent with their incorporation into this methodology.

2. The topical report develops a **[[ ]]** for the purpose of describing how such a **[[ ]]** may be obtained and for the purpose of describing how such a **[[ ]]** is subsequently applied as part of the methodology's calculation steps. In application, a **[[ ]]** must be developed and appropriately justified for the use described in this methodology. Any applied **[[ ]]** must be reviewed and approved by the NRC.

Acknowledgments

- RES/DSA – Peter Yarsky
- NRR/DANU – Ben Parks; Inseok Baek

Staff Review of NAT-9390, “Design Basis Accident Methodology for In-Vessel Events without Radiological Release

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Protecting People and the Environment

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Outline

- Review chronology
- Topical report (TR) purpose and review strategy
- Regulatory requirements and guidance
- Overview of Regulatory Guide (RG) 1.203
- Safety evaluation (SE) overview
- Limitations and Conditions (L&Cs)

Review Chronology

- June 30, 2023: Pre-application public meeting (ML23181A189)
- September 29, 2023: Submittal of TR "Design Basis Accident Methodology for In-Vessel Events without Radiological Release," (ML23272A260)
- October 31, 2023: TR accepted for review by the NRC staff (ML23303A168)
- March – June 2024: Audit conducted (ML24255A017)
- October 11, 2024: Submittal of revised TR (ML24295A202)
- December 23, 2024: Draft SE issued (ML24358A247)

TR Purpose and Review Strategy

- **Purpose of TR:**
  – Requests NRC review and approval of a proposed methodology to evaluate in-vessel DBA events that do not lead to radiological release for future applicants using the Natrium design.
- **Review Strategy:**
  – NRC staff reviewed each EMDAP step in the TR against the guidance provided in RG 1.203.

Regulatory Requirements

- **10 CFR 50.34(a)(4)**
  - Requires preliminary analysis and evaluation of the design and performance of structures, systems, and components (SSCs) of the facility to:
    - assess the risk to public health and safety,
    - determine the margins of safety during normal operations and transients, and
    - assess the adequacy of the SSCs provided for preventing accidents and mitigating their consequences.
- **10 CFR 50.43(e)**
  - Requires a demonstration of safety feature performance through analysis, test programs, experience, or a combination thereof.
  - Requires sufficient data exists regarding safety features of the design to assess the analytical tools for safety analyses over a sufficient range of plant conditions.

RG 1.203, “Transient and Accident Analysis Methods”

- Provides guidance for use in developing and assessing evaluation models for accident and transient analyses
- Evaluation Model Concept:
  - calculational framework for evaluating the behavior of the reactor system during a postulated transient or accident
  - Includes computer programs, special models, and all other information needed to apply the calculational framework to a specific event
- EMDAP includes four elements:
  1. Determine requirements for the EM.
  2. Develop an assessment base consistent with determined requirements.
  3. Develop the EM.
  4. Assess the adequacy of the EM.

RG 1.203: Element 1

Determine requirements for the EM.

- Identify the application envelope for the EM.
- Determine the figures of merit (FOMs).
- Identify the important phenomena and processes needed to evaluate event behavior relative to the FOMs.

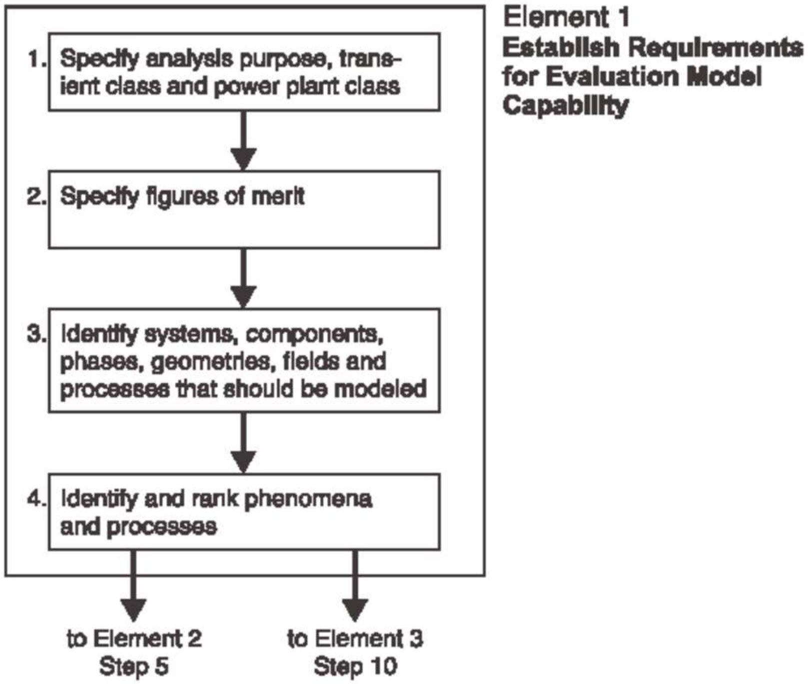


Figure 2. Steps in Element 1

Step 1: Analysis Purpose

- **RG 1.203:** Specify analysis purpose, transient class, and power plant class.
  - **Purpose:** Demonstrate the reactor operates such that all acceptance criteria are satisfied under normal operational conditions, and continued to be satisfied during in-vessel DBAs without radiological release
  - **Transient Class:** Loss of Offsite Power (LOOP), Rod Withdrawal at Power (RWAP), and Loss of Heat Sink (LOHS)
  - **Power Plant Class:** Natrium reactor
- NRC staff compared selected transients against previous sodium fast reactor (SFR) licensing efforts such as the PRISM reactor.
- NRC staff determined that the analysis the TR meets the guidance provided in Step 1 of RG 1.203 and therefore is acceptable.
- Applicability of EM limited to Natrium design as described by TR (L&C 1).

Step 2: Figures of Merit

- **RG 1.203:** Figures of Merit (FOMs) are quantitative standards of acceptance used to define acceptable answers for a safety analysis.
  - Fuel Centerline Temperature
  - Coolant Temperature
  - Time at Temperature for Peak Cladding Temperature
    - Time at temperature no failure (TATNF) criteria developed - accounts for strain, cladding wastage, and thermal creep
- TATNF criteria is used to screen whether a DBA needs further analysis, discussed in TerraPower’s TR on DBA with radiological release (ML24082A262).
- NRC staff audited internal TerraPower documents detailing TATNF development.
- NRC staff determined that the EM’s FOMs are adequate because they can be used to ascertain whether fuel has failed and whether phenomena would challenge the primary coolant boundary.
- Therefore, NRC staff determined TerraPower’s approach to Step 2 is acceptable.

Step 3: Identify EM Characteristics

- **RG 1.203:** EM characteristics are identified through hierarchical system decomposition, with ingredients at each level decomposed into ingredients of the next level down (e.g., systems into subsystems).
- TerraPower provided a hierarchical decomposition for the Natrium plant, scoped to cover the primary and intermediate systems, as well as the reactor air cooling system (RAC), intermediate air cooling system (IAC), and sodium-salt heat exchanger (SHX).
- NRC staff compared the decomposition with the description of the Natrium plant provided in the TR, verifying that all necessary ingredients were included.
- NRC staff determined TerraPower’s approach to Step 3 was acceptable as the list of ingredients is consistent with the Natrium plant description and RG 1.203.

Step 4: Key Phenomena

- **RG 1.203:** Key phenomena and processes are identified and ranked with respect to their influence on the FOMs. This is done by developing a phenomena identification and ranking table (PIRT), in which:
  - An event is divided into operationally characteristic time periods in which dominant phenomena and processes remain constant.
  - For each time period, phenomena and processes are identified.
  - These phenomena are ranked based on their impact on the FOMs.
- TerraPower developed a composite PIRT which encompassed a series of five PIRTs covering the three transients chosen in Step 1 (LOOP, RWAP, and LOHS).
  - TerraPower identified three characteristic time periods (initiation, transition, and post-scram cooling), which were consistent for all three transients.
  - Phenomena and processes were identified for each time period, and then ranked based on their importance and state of knowledge (high, medium, low).

Step 4: Key Phenomena

- NRC staff audited the TerraPower's PIRT development process, including the results of all five PIRTs and determined the process is acceptable because it followed the guidance of Step 4 of RG 1.203.
- NRC staff determined the PIRT phenomena are appropriate for the transients considered for the EM because they are consistent with the Natrium design and past SFR operating experience.
- Because TerraPower used an acceptable process to develop the PIRT and arrived at a reasonable set of PIRT phenomena and rankings, the NRC staff determined that TerraPower's approach to Step 4 and the PIRT is acceptable for the methodology scope defined by EMDAP Steps 1 through 3.

RG 1.203: Element 2

Develop Assessment Base, which:

- may consist of a combination of new and legacy experiments,
- should be consistent with requirements determined from Element 1, and
- is used to validate codes used by the EM as part Element 4

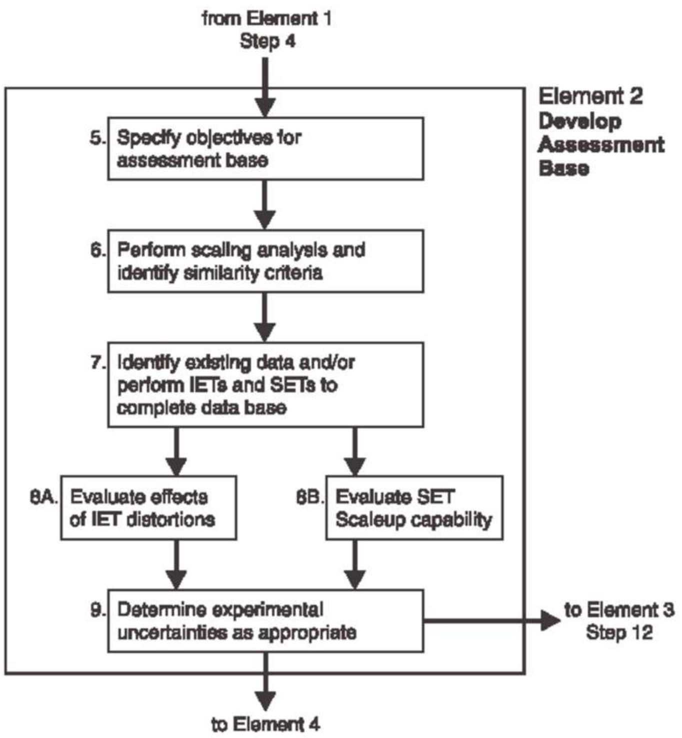


Figure 3. Steps in Element 2

Step 5: Objectives for Assessment Base

- **RG 1.203:** Determine the objectives for database that will be used to assess the EM, which should include separates effects tests (SETs) and integral effects tests (IETs).
- TerraPower's objective is to identify sufficient experimental data to form a complete assessment base for assessing the adequacy of the EM.
  - TR presents an approach that categorizes the scalability of data into three distinct areas: geometry and phenomena (Category 1), physical properties (Category 2), and phenomena character, event timing, and order (Category 3).
  - For this assessment matrix, TerraPower plans to include experimental data from at least one Category 1 IET, and all supporting SETs necessary for all highly-ranked phenomena identified in Step 4.
  - Additional Category 2 and 3 data included to provide credibility for the EM at a variety of scaling factors.
- NRC staff determined that TerraPower's objectives for the assessment base are acceptable because they are consistent with RG 1.203 which states SETs and IETs are required for EM assessment.

Step 6: Scaling Analyses

- **RG 1.203:** Scaling analyses are performed to ensure experimental data and models based on that data will be applicable to full-scale analysis of plant transients.
  – A top-down scaling analysis derives no-dimensional groups that govern similitude between facilities.
  – Bottom-up scaling analyses address localized behavior and are used to explain differences among tests from different experimental facilities to help infer expected plant behavior.
- TerraPower is developing a hierarchical two-tiered scaling (H2TS) approach to perform both top-down and bottom-up scaling analyses.
- NRC staff determined TerraPower’s approach to Step 6 is acceptable because the H2TS appropriately approaches scaling from both top-down and bottom-up perspectives to establish similarity criteria.
- NRC staff has not made a determination with respect to TerraPower's execution of Step 6 as it has not been completed. (Subject to L&C 2.)

Step 7: Experimental Data

- **RG 1.203:** Identify existing data and/or perform IETs and SETs to complete the assessment base.
  - These experiments should address the important phenomena identified in the PIRT.
  - A range of tests should be used to demonstrate the EM has not been tuned to a single test.
- TerraPower’s EM assessment matrix is planned to include data from:
  - an IET scaled to the Natrium reactor,
  - four scaled SETs,
  - experiments from previous operating SFRs (EBR-II, FFTF, and Phenix), and
  - historical IETs and SETs.
- NRC staff determined that the identified experiments are expected to provide adequate assessment data for the highly-ranked phenomena identified in Step 4 and that the initial pedigree evaluation and preliminary code assessment matrix are consistent with the guidance provided in RG 1.203.
- NRC staff has not made a determination with respect to TerraPower's execution of Step 7 because the final scaling assessment has not been completed, the scaled IET and SETs still need to be performed, and the pedigree evaluation and the code assessment matrix have not been finalized (Subject to L&C 2).

Steps 8 and 9

- **Step 8:** Evaluate IET distortions and SET scaleup capability.
  - TerraPower plans to perform this step following the completion of Step 6 and the completion of the scaled IET and SETs.
- **Step 9:** Determine experimental uncertainties.
  - TerraPower plans to follow the American Society of Mechanical Engineers (ASME) Nuclear Quality Assurance (NQA-1) standard for the scaled IET and SET experiments.
  - For experimental uncertainties associated with legacy experiments, TerraPower plans to use engineering judgement to determine the degree of compliance with NQA-1.
- NRC staff determined TerraPower's approach to these steps are adequate as they align with guidance provided in RG 1.203.
- NRC staff has not made a determination with respect to TerraPower's execution of these steps because these steps have not been completed (L&C 2).

RG 1.203: Element 3

Develop the Evaluation Model.

- The calculational devices needed to analyze the transients identified in Element 1 are selected.
- Includes choosing applicable computer codes, boundary conditions, and procedures for treating input and output information.

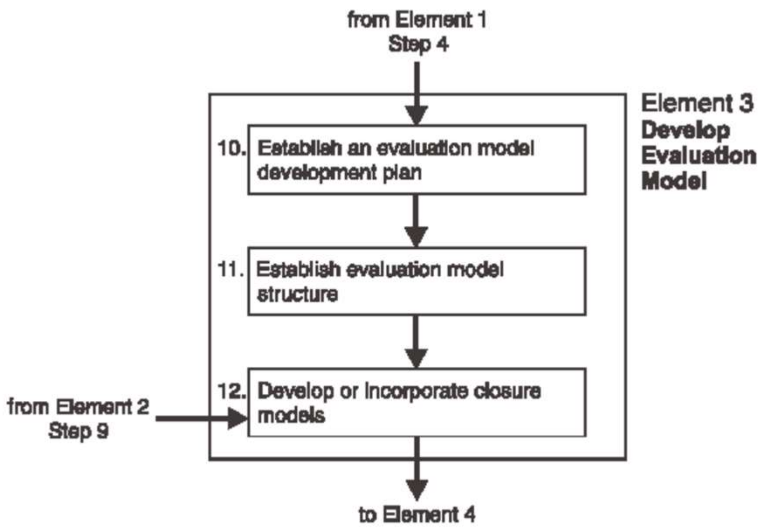


Figure 4. Steps in Element 3

Step 10: EM Development Plan

- **RG 1.203:** An EM development plan is created based on the requirements established in Element 1, including developing the standards and procedures that cover:
  - Design specifications for the calculational device
  - Documentation requirements
  - Programming standards and procedures
  - Transportability requirements
  - QA procedures
  - Configuration control procedures
- NRC staff audited documents detailing the EM's design specifications and applicable quality assurance (QA) requirements.
- The NRC staff determined that TerraPower's approach to Step 10 is acceptable because TerraPower's software design specifications and QA requirements appropriately address the six key focus areas discussed in RG 1.203.

Step 11: EM Structure

- **RG 1.203:** EM structure should include:
  - The ability to model relevant systems and components
  - The ability to model relevant constituents and phases
  - Field equations (mass, energy, and momentum)
  - Closure relations
  - Numerics (code capability to perform efficient and reliable calculations)
  - Capability to model boundary conditions and control systems.
- TerraPower identified SAS4A/SASSYS-1 (SAS), Version 5.7.1 as the main system analysis computer code to be used for the EM.
- NRC staff reviewed the SAS Code Manual and the TR to ensure all six ingredients discussed in Step 11 were appropriately addressed.
- NRC staff determined TerraPower's approach to Step 11 is acceptable.

Step 11: Systems and Components

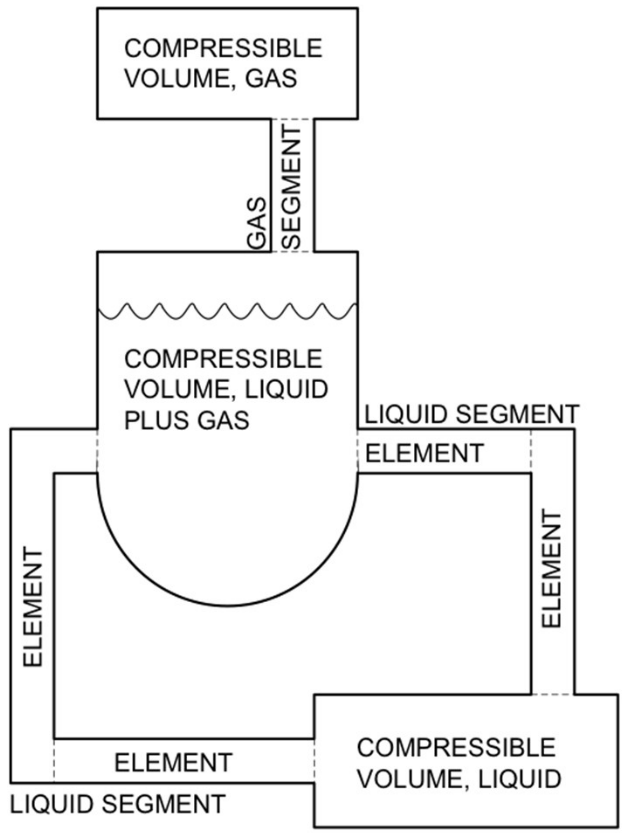
- Basic geometric modeling element used in SAS core modeling is a channel consisting of a fuel pin, its cladding, and the associated coolant and structure around the channel.
- Options for a single-pin or multiple-pin model
  - **Single-pin:** a single average channel is used to represent the average of many pins, with multiple channels used to model all the pins in the reactor
  - **Multiple-pin:** each channel represents one or more pins in a subassembly. Multiple-pin subassembly models are joined with single-pin subassembly models to model all pins in the reactor.

Step 3 Hierarchical Breakdown

- Subsystems:
  - Reactor core and core components
  - Reactor enclosure system
  - Primary heat transport system
  - Intermediate heat transport system
  - IAC
  - Control rod drive system
  - RAC
- Components:
  - Reactor vessel
  - Intermediate heat exchanger
  - Other heat exchangers (e.g., IAC, SHX)

Step 11: Systems and Components

- SAS models primary and intermediate heat transport systems through compressible volumes (CVs) connected via liquid or gas segments.
- Segments contain multiple elements.
- **CVs:** hot and cold pools
- **Elements:** core subassemblies, pipes, pumps, heat exchanger shell-and-tube sides
- SAS additionally has modules available for modeling the RAC.



Generalized Geometry (SAS Code Manual)

Step 3 Hierarchical Breakdown

- Subsystems:
  - Reactor core and core components
  - Reactor enclosure system
  - Primary heat transport system
  - Intermediate heat transport system
  - IAC
  - Control rod drive system
  - RAC
- Components:
  - Reactor vessel
  - Intermediate heat exchanger
  - Other heat exchangers (e.g., IAC, SHX)

Step 11: Constituents, Phases, Field Equations

- SAS developed specifically for analyzing power and flow transients in liquid metal reactors.
  - Capable of modeling liquid sodium in both primary and intermediate loops
- SAS allows for selecting parameters for the cover gas, including argon.
- SAS allows for air and its interactions with the RAC to be modeled.
- SAS uses mass, momentum, and energy conservation equations to predict transport of mass, momentum, and thermal energy of liquid sodium, argon, and air.

Step 3 Hierarchical Breakdown

- Constituents:
  - Liquid sodium
  - Air
  - Argon gas
- Phases:
  - Liquid sodium
  - Gases
- Field Equations:
  - Mass
  - Momentum
  - Energy

Step 12: Closure Models

- **RG 1.203:** Closure models are developed and incorporated into the EM. These are developed using SET data or can be selected from existing database literature.
- TerraPower's EM includes closure models that currently exist in the version of SAS available from Argonne National Laboratory as well as new models added to SAS developed from literature.
- The NRC staff:
  - reviewed the closure models detailed in the SAS Code Manual as well as the available literature on the newly added closure models.
  - audited internal TerraPower reports to ensure fuel assembly design parameters fell within the ranges of applicability for each correlation.
  - determined the newly added closure models are acceptable for use in the EM because they generally provide adequate predictions of key parameters.
- Subject to L&C 2, pending results of further testing related to correlation development.

RG 1.203: Element 4

Assess EM Adequacy

- Bottom-up evaluation of closure relationships used in the EM.
- Top-down evaluation of the governing equations, numerics, and integrated performance of the EM.
- Assess the ability of the EM to predict key phenomena identified in Element 1.

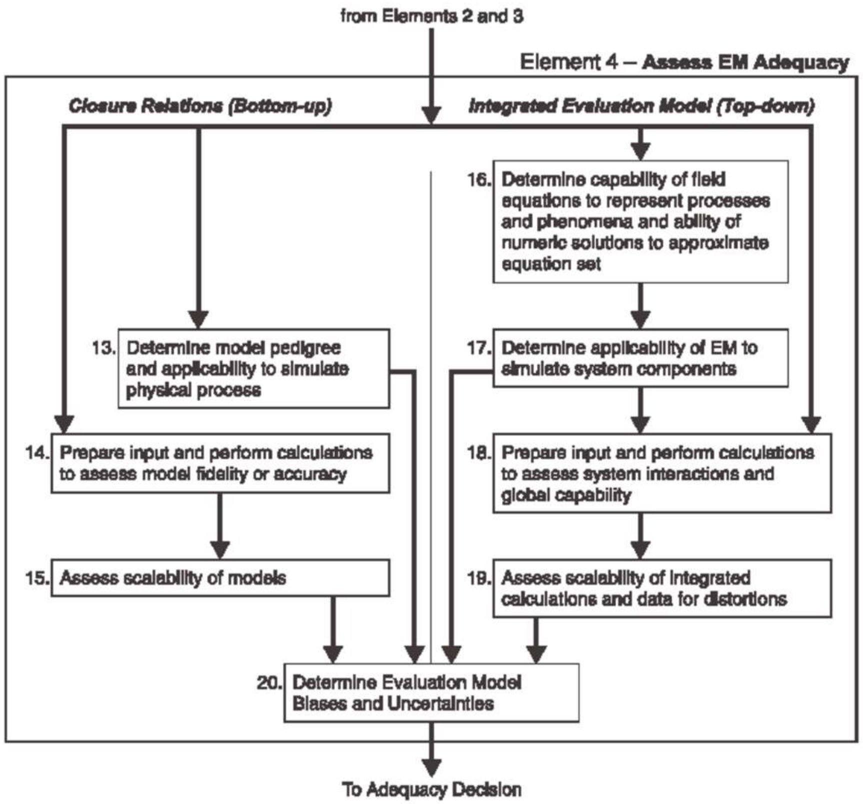


Figure 5. Steps in Element 4

Step 13: Model Pedigree and Applicability

- **RG 1.203:** The closure relationships used in the EM are evaluated based on their pedigree and applicability.
  - The pedigree evaluation relates to the physical basis, assumptions and limitations, and adequacy characterization of the closure model.
  - The applicability evaluation relates to whether the closure model is consistent with its pedigree or whether use over a broader range of conditions is justified.
- TerraPower provided an approach to Step 13, outlining the considerations for evaluating the pedigree and applicability for an example closure relationship.
- NRC staff determined that this approach is acceptable as it is consistent with the considerations discussed in RG 1.203.
- NRC staff has not made a determination with respect to TerraPower's execution of EMDAP Step 13 because it has not been performed. (Subject to L&C 2.)

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Steps 14 and 15: Model Fidelity and Scalability

- **Step 14:** A fidelity evaluation is performed by preparing necessary input data for the EM and then performing calculations to access the accuracy of the model. This can be done through validation with experimental data, benchmarking with other codes, or some combination thereof.
  - TerraPower states that SAS calculations will be performed and compared against the experiments applicable to Natrium's design.
  - NRC staff determined that this approach was acceptable as it appropriately focuses on validation of the EM relative to experimental data.
- **Step 15:** A scalability evaluation is performed to determine whether a given model or correlation is appropriate for the application based on plant conditions and the transient under evaluation.
  - TerraPower states that confirmatory calculations or justifications for the scalability of each closure relationship will be performed once experimental data from Step 7 is available.
  - NRC staff determined that this approach was acceptable as it is consistent with RG 1.203.
- NRC staff has not made a determination with respect to TerraPower's execution of Steps 14 and 15 because they have not been performed. (Subject to L&C 2.)

Step 16: Field Equation Capability

- **RG 1.203:** The capability of the field equations to represent important phenomena and the ability of the numeric solutions to approximate the equation set are evaluated.
  - For the field equation evaluation, the acceptability of the governing equations in each code are examined for the target application.
  - For the numeric solution evaluation, the convergence, property conservation, and stability of code calculations should be considered.
- TerraPower plans to:
  - validate the EM’s field equations by performing calculations using data from experiments scaled to Natrium,
  - consider the pedigree, key concepts, and processes culminating in the field equations used in SAS, and
  - consider the consistency, property conservation, and stability of the SAS code for the numeric solution evaluation.
- NRC staff determined that TerraPower’s approach to Step 16 is acceptable because it is consistent with the considerations discussed in RG 1.203.
- NRC staff has not made a determination with respect to TerraPower's execution of Step 16 because it has not been performed. (Subject to L&C 2.)

Step 17 and 18

- **Step 17:** An applicability evaluation is performed to consider whether the integrated code is capable of modeling plant systems and components.
- **Step 18:** A fidelity evaluation is performed, where EM-calculated data is compared to measured test data from available IETs. The differences between calculated data and experimental data should be determined for important processes and phenomena and be quantified for bias and deviation.
- TerraPower plans to first evaluate the capability of the EM to simulate the systems and subsystems of the Natrium plant, and then assess the system interactions and global capabilities of the EM.
- NRC staff determined the approach to Steps 17 and 18 is acceptable because the tasks planned are consistent with the considerations discussed in RG 1.203 and will sufficiently demonstrate the EM's ability to model Natrium and demonstrate the EM's fidelity.
- NRC staff has not made a determination with respect to TerraPower's execution of Steps 17 and 18 because they have not been performed. (Subject to L&C 2.)

Step 19: Scalability Assessment for Integrated EM

- **RG 1.203:** A scalability evaluation is performed to determine whether there are distortions between EM calculations and experimental data among facilities or between calculated and measured data for the same facility.
- TerraPower plans to use the scalability assessment to ensure that experimental data and EM calculations of highly-ranked phenomena agree show reasonable agreement and that the EM is sufficiently conservative.
- NRC staff determined that TerraPower’s approach to Step 19 is acceptable because it is consistent with the considerations discussed in RG 1.203.
- NRC staff has not made a determination with respect to TerraPower's execution of EMDAP Step 19 because it has not been performed. (Subject to L&C 2.)

Step 20: Determine EM Biases and Uncertainties

- **RG 1.203:** EM biases and uncertainties are determined, including whether the degree of overall conservatism or analytical uncertainty is appropriate for the entire EM.
- TerraPower plans to take a conservative approach for the EM rather than performing uncertainty analyses.
- TerraPower plans to ensure the approach is conservative by:
  - Inserting conservative biases on the nominal inputs related to highly-ranked phenomena.
  - Applying hot channel factors to the output to obtain a conservative cladding temperature.
- NRC staff determined that TerraPower's approach to Step 20 was appropriate to ensure that inputs will be biased conservatively and provide an overall conservative result, and is consistent with RG 1.203, which states that suitably conservative transient analyses do not require a complete uncertainty analysis.
- NRC staff has not made a determination with respect to TerraPower's execution of EMDAP Step 20 because the application of this approach and its comparison to experimental results have not been performed. (Subject to L&C 2.)

Conclusion

NRC staff determined that the TR provides an acceptable approach to develop a methodology for applicants utilizing the Natrium design to evaluate in-vessel DBA events without radiological release.

Limitations & Conditions:

1. The NRC staff's determinations in this SE are limited to the Natrium design described in Section 1.2 of the TR and this SE, including the use of Natrium Type 1 fuel. An applicant or licensee referencing the methodology developed in this TR must justify that any departures from these design features do not affect the conclusions of the TR and this SE. Additionally, this methodology was developed to analyze certain design basis accidents as discussed in TR section 2.1 and this SE (and as defined in NEI 18-04); use of this methodology for other kinds of analyses must be justified.
2. The NRC staff noted that execution of the steps 6, 7, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19, and 20 of the EMDAP, as well as sensitivity studies discussed in section 2.5 of the TR and section 3.1.4 of this SE, have not been completed. An applicant or licensee referencing the methodology developed in this TR must submit documentation and justify that these steps of the EMDAP have been completed to a state that is appropriate for the intended licensing application.

Questions?

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