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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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TERRAPOWER SUBCOMMITTEE

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WEDNESDAY

MARCH 19, 2025

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

COMMITTEE MEMBERS:

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MATTHEW W. SUNSERI, Member

ACRS CONSULTANTS:

DENNIS BLEY

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

KENT HOWARD

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

8:30 a.m.

CHAIR ROBERTS: The meeting will now come to order. This is the second day of a meeting of the TerraPower Natrium Design Subcommittee of the Advisory Committee of Reactor Safeguards. I am Tom Roberts, chairman of today's subcommittee meeting. ACRS members in attendance in person are Ron Ballinger, Craig Harrington, Dave Petti, Greg Halnon, Bob Martin, Scott Palmtag, Matt Sunseri, and myself. ACRS members in attendance virtually via Teams are Vesna Dimitrijevic and Vicki Bier. And we have a consultant, also via Teams, Steve Schultz. If there's any other members or consultants that I missed, please let me know now so that we can get that on the record. Okay. Hear nothing.

Kent Howard of the ACRS staff is the Designated Federal Officer for today's meeting. No member conflicts of interest have been identified, and we have a quorum.

As I mentioned, this is the second day of a meeting that we're holding to get a briefing on four Natrium topical reports. Just in case somebody wasn't down yesterday, I wanted to repeat the summary of where we are in terms of what these four topical reports represent in our review. The staff is currently reviewing the construction permit application submitted by TerraPower in March of last year, and they'll be presenting the results of that review to us starting in late summer or early fall of this year. So this meeting is not intended to review the construction permit application. That's still pending.

Rather, TerraPower had submitted 11 foundational topical reports in advance of their construction permit application, and the staff reviews them separately from the construction permit application. They review topical reports when warranted to maximize lineup between all parties and reveal safety concerns as early as possible in the process where they're easier to resolve.

This project previously reviewed five -- we previously reviewed five topical reports. We determined two did not warrant our review, and we're reviewing the remaining four topicals at this two-day meeting.

Today, we'll cover the methodology for analyzing the consequences of radiological releases, and that review will be led by Bob Martin. And we're also reviewing the methodology for estimating the radiological source term, and that now will be led by member Dave Petti.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act, or FACA. The NRC has issued regulations that implement FACA. Per these regulations and the Committee's bylaws, the ACRS speaks only through its published letter reports. All members' comments shall 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. They 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 of public transparency in regulation of nuclear facilities, draws opportunities for public input and comment during our proceedings. We received no written statements or requests to make an oral statement from the public, but we set aside time at the end of this meeting for public comments.

Portions of this meeting will be closed to protect sensitive information as required by FACA and the Government in the Sunshine Act. Attendance during the closed portions of the meeting will be limited to the NRC staff and its consultants, applicants, and those individuals and organizations who have entered into an appropriate confidentiality agreement. We will confirm that only eligible individuals are in the closed portion of the meeting.

The subcommittee will gather information, analyze relevant issues and facts, and formulate proposed 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 so that they can be readily heard. If you're not speaking, please mute your computer on Teams or by pressing *6 on the phone. Please do not use the Teams chat feature to conduct sidebar discussions relative to the presentations. Rather, limit use of the 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 since the ceiling microphones are live.

For the presenters, your microphones are unidirectional. You need to speak directly into the front of the microphone to be heard. So we'll coach you as we proceed in this meeting. 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 the NRC's website.

With that, our first topic is the radiological release consequence methodology, and I'll turn it over to TerraPower to begin the presentation.

MR. PEARSON: Good morning. I'm Eric Pearson, a radiological analysis engineer. I'll be presenting on the radiological release consequences topical report.

Thank you. Next slide, please. So this topical report describes three different evaluation models, or EMs. First is the licensing basis event, or LBE EM. The second is the design basis accident, or DBA, or EM. And the third is the control room habilitation, or CRH, EM. I'll additionally be discussing some modifications that can be made to the LBE EM to generate radiological consequences for the emergency planning zone, or EPZ, sizing methodology.

I like to clarify at the top here that,

technically, within the licensing modernization project, as defined in NEI 1804, DBAs or a subset of LBEs, but, for the scope of this presentation, I'll be referring to them explicitly.

Next slide, please. Starting with the objectives of the LBE EM, the goal is to calculate four different radiological consequences. The first is the 30-day total effective dose equivalent, or TEDE, at the exclusionary area boundary, or EAB. The second is the probability of exceeding 0.1 rem 30-day TEDE at the safe boundary, so a different distance there. The third is the risk of early fatality within one mile of the EAB, and the fourth is the risk of latent cancer fatality within ten miles of the EAB.

For all four of these consequences, we're considering three different dose pathways. Those are inhalation, submersion, and groundshine. Consequence No. 1, the 30-day TEDE, is used to generate the frequency consequence target, and Consequences 2 through 4 are used to generate the quantitative health objectives, which are an integrated risk metric in the LMP.

Next slide, please. Consequences in the LBE EM are calculated probabilistically using the WinMACCS code. The WinMACCS code includes both computational nodule and graphical user interface for gravity. For brevity, it will be referred to simply as MACCS.

Inputs to MACCS code were developed from several sources of input guidance. Those include NUREG-1150, NUREG-1935, and NUREG-CR-7270. And I'll note that 7270 is a recent guidance document that was released during the evolution of this topical report that was referred to heavily.

Next slide, please. One important aspect of the LBE EM is the uncertainty treatment. The MACCS code accepts a very large number of inputs. To determine which of those are important to radiological consequences, we first performed sensitivity studies to determine which uncertain parameters radiological consequences are sensitive to. And then for those inputs that are both uncertain and radiological consequences are sensitive to, we apply one of two uncertainty treatments. The first is deterministic, simply applying a conservative value which bounds the uncertainty. That approach is always used for the DBA and control room habitability EMs discussed later. And second is probabilistic, randomly sampling parameter values from a representative distribution computing the corresponding consequences, and repeating that process many times to determine distribution results and selecting the fifth mean and 95th percentile results from that distribution. The probabilistic approach is always used in the LBE ME to handle weather uncertainty.

MEMBER MARTIN: You obviously must have seen my green light go on because you -- just first, real quick, the probabilistic approach is just a standard Wilks approach, you know, whatever, best estimate plus uncertainty; is that correct?

MR. PEARSON: It's a good question. In general, we do require at least the Wilks approach to ensure that we have the 95th percentile results with 95-percent confidence. However, in practice, for weather uncertainties specifically, we tend to take many more samples to more accurately quantify the distribution.

MEMBER MARTIN: To populate your uncertainty models, is the intent to be site specific or you're looking to be generic? I imagine, up to this point, you've been generic, right? But is the intent, say, to cover all sites with one analysis? For every future Natrium plant, you'll have site-specific information. Of course you will, at least as far as the met data is concerned.

MR. PEARSON: It's a very good question. The consequences for LBEs are used in many places for informed decisions in the design, such as SSC classification. And, for that reason, it may be desirable to be generic to avoid having to fundamentally redesign parts of the reactor for different sites. However, that decision will be made on application and isn't --

MEMBER MARTIN: Fair enough. It's early.

CHAIR ROBERTS: A quick question. There's a reg guide that calculates a 95-percent sector meteorology and 99 percent for the worst sector. Is that something you're doing as part of the deterministic uncertainty, or is that just not done in LMP at all?

MR. PEARSON: Yes. That reg guide is related to how atmospheric dispersion factors are calculated. Those are used in both the DBA and control room habitability evaluation models. However, the methodology for calculating the chi over q is not captured in this topical report. We simply take them to an input.

CHAIR ROBERTS: Okay. Thanks.

MEMBER PETTI: Just a broader question. Yesterday, you know, we heard the presentations. It's not a best estimate plus uncertainty in the, let's call it the thermal hydraulic model. It's more of a bounding hotspot factors. Yet, here, it's going to be probabilistic, so it's going to kind of be patchwork in terms of, you know, starting with the core and then the source term to the dose. It could vary in each piece.

I'm trying to mentally kind of put that together in my head because what I'm used to seeing is you either do all one or you do all the other. This looks like a hybrid. Is that --

MR. PEARSON: We do have separate treatments. DBAs are treated explicitly, which is why we had to break our radiological methodology into different evaluation models.

MEMBER PETTI: Oh, okay. Got you. So the DBA will all be deterministic.

MR. PEARSON: That's right. Great question. Following the NRC review of our topical report, there were a couple of significant changes made highlighted here. The first is the use of the CHRONC, or chronic, module in the MACCS code to account for the contributions to the weight and cancer fatality that occur after the accident duration. So without the use of the CHRONC module, consequences are determined fully for that 30-day accident duration. With the CHRONC module turned on, we, additionally, account for the dose that's contributed due to radionuclides deposited on the ground in the area surrounding the plants for the 50 years following the accident duration. So the dose pathways considered in the CHRONC module are resuspension inhalation, kicking up those deposited radionuclides and inhaling them, and groundshine.

MEMBER PETTI: So it's a 50-year exposure, not a 50-year dose commitment, because those are different.

MR. PEARSON: That's correct.

MEMBER PETTI: So you're assuming that people will get dose for 50 years.

MR. PEARSON: That's correct.

MEMBER PETTI: Okay.

MR. PEARSON: The second change was the use of Federal Guidance Report 11 and 12, Dose Diversion Factors, to calculate TEDE dose. Previously, we had been using ICR P60-based dose conversion factors. FGR 11 and 12 were identified as more appropriate dose conversion factors in the audit matching the TEDE definition in 10 CFR 50.2.

MEMBER PETTI: Does that make a big

difference?

MR. PEARSON: Some informal study showed us it was about a 10-percent difference in the conservative direction.

CHAIR ROBERTS: Eric, your presentation isn't very long, and we kind of separately have noted how it's a little unfortunate we didn't have the source term first. Obviously, it is an input into the Radiological Consequences Methodology.

You'll probably get into it in the later discussion, but can you just kind of briefly, you know, talk about the different source terms and how they get implemented into MACCS?

MR. PEARSON: That's a great question. Yes. So that standard handoff map we have between the source term evaluation model and the radiological consequence evaluation model is a release-to-environment matrix that gives us the release of each radionuclide for many time steps throughout the accident duration, so we take up the accident at the release-to-environment point that model the atmospheric dispersion and resulting dose consequences from there.

CHAIR ROBERTS: So they're different phases, right. You think in the tradition of light water reactors, Reg Guide 193. It might be a source term question on how you establish the release timings. Well, certainly, the source term would give you the releases, and then there's the timing.

So how fine is that, say, segmentation of the source term, you know, over time? And I guess is it the 30-day releases that you're segmenting?

MR. PEARSON: That's a very good question. Yes. In general, the time-stepping does change depending on which code is used in the source term evaluation model to determine the release matrix. In the radiological consequence portion, we intend to be generic to handle that matrix accurately, no matter how it was developed into our upstream. And we can talk more about how we do that in the proprietary session.

CHAIR ROBERTS: Sure. Sure. I think maybe, at a high level, that kind of information, again, coming from the source term, to get ahead of ourselves, is going to be subject to a considerable amount of uncertainty. Even though you're doing this, more or less, in a best estimate sense, are there still kind of maybe realistic conservatisms that get incorporated into kind of setting up that table, time release table, whether to be generic or site specific but just to cover inherent but realistic uncertainty?

MR. PEARSON: Yes. Source term uncertainty, in particular, was an area we focused on and handled that correctly. At the time the topical report was put together, we were still sort of developing that methodology. So as far as the topical report itself, we simply say that the application will have to describe and justify the uncertainty handling the source term.

Next slide, please. And then the last topic we'll touch on for the LBE evaluation model, the modifications that need to be made to generate radiological consequences for the plume exposure pathway EPZ sizing methodology. In general, that sizing methodology is established in a different topical report, and that's NAT-3056; but we'll touch on the radiological consequence portion here.

Two different radiological consequences are considered: the four-day TEDE at the plume exposure pathway EPZ boundary and the one-day acute red bone marrow dose at the EPZ boundary. Both of these can be calculated using the LBE EM with two small changes. The first is the reduction of the accident duration from the nominal 30-day accident scenario down to either four or one day, depending on the consequence being calculated. And the second is the specification that the MACCS code output, either the TEDE or the acute red bone marrow dose at the EPZ boundary distance.

MEMBER PETTI: So just a question on the bone marrow dose. It, to me, reads as a surrogate. Why did you go that way as opposed to the more traditional -- there?

MR. PEARSON: That's a good question. I know there's extensive discussion of it in the engagement for the EPZ sizing methodology topical report. As far as the involvement at the radcon team they're the -- we were simply asked to produce the radiological consequence that they were needing for their methodology, and so we did using the LBE evaluation model, as we described here.

MEMBER MARTIN: A more generic question. So the NEI 1804, it's really intended to cover the whole spectrum of events, you know. What we'll call the frequency consequence plot in there includes, you know, really the operational conditions that might impact facility workers that really govern under 10 CFR 20. Is the intent of these analyses to cover that whole spectrum, or are we really just looking at kind of what we talked about yesterday, the DBAs without and with radiological releases? Is it a more narrow focus of this methodology, or is it intended to cover the whole spectrum of frequency and consequences?

MR. PEARSON: That's a very good question. Yes. In general, the LBEs that we analyze for this methodology cover the whole spectrum of frequencies. However, the dose consequences we consider are specifically for the off-site dose that we've described, so I think it satisfies a specific aspect of the LMP with those other --

MEMBER MARTIN: Okay. But the other domain would be captured in another methodology?

MR. PEARSON: That's correct.

MEMBER MARTIN: Okay. TBD.

MEMBER PETTI: But you do plan putting on the frequency consequence curve the data, right?

MEMBER MARTIN: All the data. All the data. I know it's methodology. I guess maybe it's more of a Tom question. Will we see kind of a PRA topical or something like that? Is that in the pipeline? Obviously, it feeds into this, as well, at some point.

CHAIR ROBERTS: I'd ask that to Reed. Nothing I've seen except for the construction permit application covers the PRN.

MEMBER MARTIN: Okay.

(Simultaneous speaking.)

CHAIR ROBERTS: It's going to be a topical, yes.

MEMBER MARTIN: Part of the construction application. Thanks.

MR. PEARSON: That was my last slide on the LBE evaluation model.

Switching over to the DBA evaluation model, the objectives here are to calculate two dose consequences. The first is the highest TEDE dose received over any two-hour period at the EAB, and the second is to calculate the 30-day TEDE dose received at the boundary of the low-population zone.

For both of these dose consequences, we consider the inhalation and submersion dose pathways. Both of these dose consequences have the same regulatory limit of 25 rem, and the methodology we used to calculate them is closely aligned with the guidance in Regulatory Guide 1.183 revision 1. We performed this calculation using an internally-developed code. There will be more on the next slide.

MEMBER MARTIN: Kind of a standard question. We mentioned the word internally-developed code. What are you doing for V&V?

MR. PEARSON: That's a great question. All the software that we described within the radiological consequences topical report are pre-verified using GE's 10 CFR Part 50 Appendix B-compliant software quality assurance program.

MEMBER MARTIN: So I imagine with, you know, dispersion codes, there are standard sets of benchmarks for validation.

MR. PEARSON: For the RRCAT code specifically, are you asking about the details of how the V&V was performed for that?

MEMBER MARTIN: Yes, I am.

MR. PEARSON: Yes. So for the verification aspects, we had, of course, code access to the mathematical models that were encoded within because we encoded them. So we were able to perform a large number of analytical verification to ensure that those were correct. And then, as far as the validation piece goes, we largely relied on comparisons to the benchmarks against the RADTRAD code.

MEMBER MARTIN: Now, RRCAT, is that brand new for Natrium, or is that something GE and Natrium have agreed, you know, something that GE really developed -- I'm trying to understand, you know, kind of a historical record of RRCAT.

MR. PEARSON: Yes, it is a new code.

MEMBER MARTIN: Okay. It is brand new.

(Simultaneous speaking.)

MEMBER BALLINGER: This is Ron Ballinger. You know, there's a revision 2 for 1.183 sort of on the way to the street. Does that make a difference?

MR. PEARSON: The main difference in the guidance that we follow between revision 0 and revision 1 is the guidance regarding the atmospheric diversion --

MEMBER BALLINGER: Oh, okay.

(Simultaneous speaking.)

MR. PEARSON: -- structuring, which I believe is the same in the --

MEMBER BALLINGER: Okay. Yes, yes.

CHAIR ROBERTS: I'm wondering if you can clarify what you said earlier about chi over q not being part of this work. This slide says that the revised RADTRAD code, you'd use the same correlation as RADTRAD does, and I assume that's Gaussian plume dispersion with a certain set of coefficients that are selected. The topical report does talk about that also.

So it seems like, at least for the design basis, you have settled on the methodology. Is it right, your earlier comment about the DBE methodology that you haven't settled the chi over q approach yet?

MR. PEARSON: Yes. Good question. For both the RADTRAD and RRCAT codes, however you factor their use, are used simply as an input, but they are calculated externally using other codes. Typically, an ARCON or a PAVAN would be used for that.

For the LBE methodology, atmospheric dispersion is modeled within the MACCS code itself, so there is no explicit quantification of chi over q in the input. That's all internal to the MACCS code.

CHAIR ROBERTS: Okay. And that's what you're using.

MR. PEARSON: That's correct.

CHAIR ROBERTS: Okay. Thank you.

DR. SCHULTZ: This is Steve Schultz. You say the control rooms modeled is a single compartment exchanging air with a semi-infinite plume. You also have shine dose associated with the control room. Is that part of the analysis with RRCAT, or is that separate?

MR. PEARSON: That's correct.

DR. SCHULTZ: That it's separate?

MR. PEARSON: Oh, I'm sorry. Yes, we consider all three shine dose conversion pathways -- sorry -- all three dose pathways, inhalation, submersion, and shine dose, and that calculation is performed using the RRCAT code.

DR. SCHULTZ: Okay. Thank you.

MEMBER PETTI: It sounds like he answered your next slide.

MEMBER MARTIN: I'm curious about shine dose. So the confinement around the reactor, there's an HVAC system. You would expect activation of argon in particular, maybe some nitrogen. Nominally, you might take that up the stack and then release it. So is that still in the Natrium design? Do you still have the air handling and the release, you know, of the stack? But then wouldn't you have, you know, you really don't have as much, say, shielding that might come with a, you know, a hardened containment. You get, you know, activation beyond the building. Is that, in some way -- that would be expected to be less, obviously. Is that getting counted as a separate source term?

MR. PEARSON: Very good question. I would like to keep most of the conversation about shine calculation for the proprietary session. But at a high level, you do still account for shine from a compartment containing radionuclides before release, shine from the plume external to the control room, and shine from radionuclides that build up on HVAC equipment --

MEMBER MARTIN: Okay. So it's really in one of the source term buckets.

MR. PEARSON: So as we've discussed a little bit, the internally-developed code is the Release Radionuclide Consequence Analysis Tool, or RRCAT. That RRCAT code models, or to environment, resulting dose consequences very similar to the RADTRAD code. By similar, I mean that atmospheric transport is handled using undepleted atmospheric dispersion factors, which are calculated separately and then input into the code. Offset receptors are modeled as submerged in a semi-infinite plume, and the control room is modeled as a single compartment exchanging air with the semi-infinite plume.

The main difference between the RRCAT code and the RADTRAD code is the RRCAT code accepts the source term release-to-environment matrix as an input while the RADTRAD code does not. So because we have these separate source term and radiological consequence evaluation models, a handoff is kind of in the middle at that release-to-environment point, and so the RADTRAD code isn't able to accept that release-to-environment matrix as an input, so we, instead, developed the RRCAT code to perform subsequently the same calculation but accepting that release-to-environment matrix without any reduction in the number of time steps taken or nuclides tracked.

Next slide, please. Moving on to our last evaluation model, we have the control room habitability evaluation model, which seeks to calculate the 30-day total effective dose equivalent received within a control room, including submersion, inhalation, and shine dose pathways. The regulatory limit for that dose is 5 rem. Again, that's being calculated with the RRCAT code following a methodology that's closely-aligned with Regulatory Guide 1.183 revision 1.

That's all I have. I'd be happy to take any additional questions.

MEMBER BALLINGER: This is Ron Ballinger. Again, I keep coming back to 1.183. The updated limit is 25, up to 25.

MR. PEARSON: Oh, okay.

MEMBER BALLINGER: So I'm curious as to whether or not that makes a difference. Revision 2 --

MEMBER HALNON: It's up to 25 based on

(Simultaneous speaking.)

MEMBER HALNON: It goes to 10, I think --

MEMBER BALLINGER: Yes. If you look at --

(Simultaneous speaking.)

MEMBER PETTI: They're coming out with new dose criteria.

MEMBER BALLINGER: So it's 10 rem, and then there's a 25 under certain circumstances.

MEMBER PETTI: And that's still a draft --

MEMBER BALLINGER: Yes, yes, I know. It said it's approximately on the street.

MEMBER PETTI: Yes. It's out for comments.

MEMBER HALNON: Eric, this is Greg. One quick question. Your slide said you align with 1.183, and you said you closely align. Was there a distinction there where you took some exceptions in the 1.183 rev 1?

MR. PEARSON: No. I just want to highlight that Reg Guide 1.183 was both the source for development and the dose consequence portion. We are fortunately involved in dose consequence piece.

MEMBER HALNON: Okay. Thank you.

MEMBER MARTIN: In the source term

presentation we have later, will we talk about the contributions, the different source term source buckets that will contribute to control room dose, that detail, as opposed to just talking about it now? If we get it later, that's fine.

MR. PEARSON: It will certainly be covered later. If not, by the source term team --

MEMBER MARTIN: Okay. Because, obviously, you know, we're familiar with light water reactors, and it should be different, you know, for Natrium. Okay. We can touch on that later.

CHAIR ROBERTS: Are there any other questions for the applicant on this topical report?

DR. SCHULTZ: This is Steve Schultz. Just one. You mentioned in your slide or what you expressed it was that you added the use of the CHRONC module in MACCS after the interactions with the staff. Was that due to the interactions with the staff, or is that something you determined you would do on your own?

MR. PEARSON: I would say that's something we determined to do on our own. When the staff questioned how we were best calculating the latent cancer fatality risk, we identified that as a gap in our model that we needed to close, so we decided to leverage that module.

DR. SCHULTZ: Okay. Thank you.

MEMBER PETTI: So you, basically, need to compare to the QHOs.

CHAIR ROBERTS: Hearing no additional questions for the applicant, let's go ahead and transition to the NRC staff evaluation of this topical report.

Okay. We'll take a break for about two minutes to change out the presenters and the slide presentation.

(Pause.)

CHAIR ROBERTS: Okay. When you're ready, go ahead.

MR. ATKINSON: Good morning, everyone. My name is Deion Atkinson the team project manager for the TerraPower Natrium project team. I'm the lead project manager on the Radiological Release Consequences topical report that will be discussed today.

I just want to start off by saying it's a pleasure to be here today. Thank you all for being here in attendance. Sitting with me for this presentation is Michelle Hart, NRC senior reactor engineer who is also responsible for the technical review of the consequences topical report and technical reviewer for the Natrium project. In addition to Michelle, we also have Zach Gran here seated next to us who is also a reactor scientist, as well as the NRC technical reviewer for the Natrium project.

On this slide, it shows how the staff presentation will be conducted, involving a description of the staff review, chronological order of the review, an old review of the topical report, relationships of this topical report to elder topical reports, an overview of the evaluation models and limitations and conditions, and, finally, staff conclusions on this topical report.

On this slide, it goes into more description of the review staff that were involved of the review of this topical report. As you can see, this involves staff from the technical branch, too, the Division of Engineering and External Hazards, and then also the Accident Analysis branch.

I will now turn over the presentation to Michelle Hart.

MS. HART: Good morning. So the review chronology, you know, to go into several terms, they did send in their first version of the topical report.

We did find it acceptable in 2023, December. We did conduct a regulatory audit to gain further information and understanding of the topical report. We have a report on that, as well.

After that audit, TerraPower did submit a revision to the topical report, and they did renumber the topical report, so, you know, some of the references, you have to understand, you know, there's a new number for that. And then we issued the draft safety evaluation in February of this year.

There is a related TerraPower topical report. As you know, there's the construction permit for Kemmerer Unit 1.

Next slide, please. So the topical report overview. This topical report is intended for use in the Natrium license applications using the licensing modernization project approach. It's a methodology to determine the radiological consequences given a source term, and there are specific source terms that are input to this methodology.

In the topical report, no specific calculations are provided or approved for use. And the topical report provides the 3 EMs that they talked about earlier and then an appendix to adapt the licensing basis EM for use in emergency planning zone sizing.

Next slide, please. As we talked about earlier, there are two other topical reports that are closely related to this methodology, and that is the source term methodology, which is input to this methodology for consequence analysis, and then also the plume exposure pathway emergency planning zone sizing methodology, which output from this methodology is used in that methodology.

Next slide, please. So to go into the licensing basis event evaluation model, you know, TerraPower has described what the purpose of that is. It's intended to be used by the applicant in the NEI 1804 LMP methodology, so that's looking at, you know,, all of the events. Like, you asked about the question if it was all of the frequency. It is not used for the design basis accidents which are derived from the DBEs in the licensing modernization project methodology that is described in the DBA EM, as well as the control room habitability ME.

Because this is a PRA-ish analysis in the LMP methodology, we did use information from the PRA standard for non-light water reactors to help us evaluate the methodology. Their topical report does state that their evaluation model does use the MACCS computer code, which is an NRC-developed code, so we do understand its use. And we reviewed the inputs, model parameters, technical rational, risk metrics, and pertinent details associated with the MACCS model execution for the purposes of evaluating the radiological release consequences. And we did have help from our colleagues in research that run MACCS a little bit more than we do so that we could understand their information in the topical report about how they use the code.

Next slide, please. As I just said, because the EM addresses PRA-related consequence analysis information, we used information in Reg Guide 1.247, which is the reg guide which endorses the non-light water reactor standard, PRA standard for trial use and, particularly, we used the subject matter areas that are described in the consequence analysis technical element from the PRA standard. And those are these subject matters as listed here, rated by release characterization, site characterization, and all the rest. And we will describe, you know, our findings against these considerations as we go through the rest of the presentation.

Next slide, please.

MEMBER MARTIN: Michelle, this is Bob. Is this the first time you all reviewed MACCS in the context of a licensing methodology? Obviously, it's tied to informing the DBAs.

MS. HART: Correct. This is the first time that somebody is proposing to use MACCS for the safety analysis. We have reviewed the use of MACCS for the environmental consequence analysis for the environmental report that they provide; but, as far as reviewing a methodology to determine safety analysis results, this is the first time.

MEMBER MARTIN: So we heard earlier that, you know, you're, basically, using a best estimate plus uncertainty approach. You know, the only real paradigm in the regulatory basis for that is Reg Guide 1.203. That was not mentioned, of course, by TerraPower earlier.

Did you, you know, consider some of the guidance in Reg Guide 1.203 in your review of how they're using MACCS? Now, kind of part of that is the PIRT, and it's a discussion of PIRT that --

MS. HART: We did not explicitly consider information from Reg Guide 1.203 in review of the consequence analysis. I think, you know, it's a little bit more well established, to a certain degree, on how to do the atmospheric transport in the context of doing safety reviews or -- not safety reviews -- reactor safety studies, so things like SOARCA and our use of MACCS in general. You know, there's not a lot of different ways to go about doing the analysis; I can put it that way. So I didn't think it was necessary.

MEMBER MARTIN: So it kind of comes down to a quality program type consideration. We understand that, of course, with maybe PRA-based methodologies, it's a little different than what you'd expect for deterministic safety analyses. Obviously, these are being used more in a qualitative sense to inform the DBAs, so, you know, the precision is not important. Really what's important is more the relative magnitudes of the consequences versus the frequencies.

So I'm talking myself into, you know, this is all just fine because it is the paradigm for QA has been adapted for the PRA models, as opposed to traditional Appendix B approaches that define our deterministic safety analyses.

MS. HART: Right. And I think, you know, the gut feeling that we have is there's a lot more variability within the source term aspect and the uncertainty in that. They have a high, you know, impact on the results.

Now, of course, the dose is directly proportional to the atmospheric dispersion, so you want to make sure that you do that. But the atmospheric modeling is similar as to what we have found acceptable for design basis accident analysis. The LBE EM is not directly used to show compliance with the off-site dose criteria. You then pass, you know, the different source term to the DBA EM for that purpose, but the LBE EM is used to help you determine your SSC classification and, you know, the event classification, as well. But, for the most part, the SSC classification, as well as doing that risk comparison, that integrated risk comparison that the licensing modernization project process has you do.

So the numbers have to have some amount of precision. They don't have to be completely accurate, as you're trying to say --

MEMBER MARTIN: I'd imagine not only is this the first time you've seen MACCS used in this way, but it's really in the context of LMP.

MS. HART: Correct.

MEMBER MARTIN: You must have had some pretty interesting conversations that, you know, go beyond any NEI 1804 and, you know, solidify, you know, maybe your expectations, you know, for future reviews. Do you maybe anticipate capturing some of your review of best practices in some way, given that this is kind of a first-of-a-kind type review?

MS. HART: I think, as we finalize our review of the Kemmerer Unit 1, you know, we will have some better information. It won't be a complete look yet even in that case because it is a construction permit and it is preliminary design information. But, you know, we are also going to be having another LMP application coming in soon.

So, you know, we can capture these lessons that we learn as we go through, but I don't think we'll see a complete picture until we've had at least -- yes. And I would like to see what happens with the other application because I think they're approaching it slightly differently. And so we may learn some things that, may unlearn some things that we thought we learned with Kemmerer.

MEMBER PETTI: Michelle, the thing that I'm interested in, and, yes, I agree with you until you get to the OL, there is this, let's just call it a gray area in terms of what do you really need for a CP in the LMP approach? I mean, PRA is the obvious question, but we're seeing fingers of that question in other areas. This is another one. So I just encourage that, you know, I think for future applicants. What do you need for CP, if there's anything in the next few to capture because I think it will be valuable downstream.

MS. HART: Yes. Understood. Thank you.

MEMBER DIMITRIJEVIC: Hi. This is Vesna Dimitrijevic. This is because the concentrating on consequences, you know, an FC curve, and not on the frequencies and the real LV selections and things like that. So some big picture how all of this will, you know, fit together should be, you know, come out of those simulations because, you know, from my point of view, this is, I mean, we are sort of discussing elements of Level 3 PRA here, you know, in this evaluation of the consequences, and you're using the PRA guide for consequences, but, you know, to fit the FC curve, that evaluation of the frequencies and the sequences and using source terms. It should also be part of, you know, some TR submissions or discussions.

All right. This is just my note on this.

MS. HART: Thank you. Is there any further questions? Okay. Let's go to the next slide, please.

So the first topic is the radionuclide

release characterization. That is, you know, the attributes of the radiological release needed to evaluate radiological consequences, such as, you know, the isotopes that you look at, the chemical form, and features like that.

So our review of the information in the topical report, as supported by the audit, was that their proprietary isotope sensitivity method that they used to determine which isotopes to evaluate is acceptable because it ensures all risk-significant radionuclides are identified. It includes considerations such as the radiological half life, biological hazard, and relative abundance of the radionuclides in the core.

And then there are other proprietary methods. The adaptive plume algorithm is acceptable because it would likely result in conservative dose results, and the results have low sensitivity to the number of plume segments that they model within MACCS as taking that release matrix that they talked about and modeling it as a release to the atmosphere over time.

Are there any questions about that?

MEMBER PETTI: Just kind of a question, and it may be more appropriate for the source term one, but, you know, they're going to be releasing a lot of these releases and some activated. The oxidation of sodium in the air in the dose calculation, is everything assumed to be oxides in terms of a body absorption perspective? You know, compared to light water reactors, is there a difference there that has to be considered?

MS. HART: Yes. I think, you know, as far as what's being released is perhaps more of a source term question. As far as the dose conversion factors and the modeling in MACCS, you can choose the appropriate dose conversion factors. There is no transformation within the environment that MACCS does well, if that was the question.

MEMBER PETTI: Yes. Okay. The question is what is really coming out of the reactor in the accident, you know, to what MACCS assumes is the chemical?

MS. HART: So MACCS does not necessarily assume anything. The analyst can choose the appropriate application, I mean, dose conversion factors and model, you know, based on the release matrix that you're given from the source term methodology. So there are some user choices that are made here. The methodology does not direct them, and it would be something that we would have to review in the implementation that they do. It's not, you know, the methodology is kind of, more or less, a guidepost on what the analyst should do, the decisions that they should make, using the MACCS methodology or MACCS code to determine the consequences.

Next topic is site characterization. So in this case, you know, the objective of the site characterization is to determine the consequences in the vicinity and region of the site out to a distance of 50 miles potentially. The NRC staff determined that the treatment of site characterization is acceptable. They use a uniform population distribution which is conservative for the use for the LMP, which you're not looking at the consequence to the actual population, you're looking at consequences to help you determine your design.

Land use information, such as, you know, amount of farm land and things that would go to determining costs from cleanup or anything like that has a negligible impact on the calculation of dose quantities for the LMP because that is not part of the consideration. The consideration is dose to an individual and risk within certain distances for comparison to the QHOs, and the approach is consistent with previous NRC staff's use of the MACCS code in reactor safety studies, such as the SOARCA or the Level 3 PRA.

CHAIR ROBERTS: Kind of pinning to a question that Bob had asked earlier, this says that there's a generic site is what this says, and then each site has to go be evaluated to determine if the generic site is conservative. Is that the basic approach?

MS. HART: As far as population, it's a generic, you know, you're just doing like a grid. As far as the other aspects of siting, they do say to use site characteristic meteorology or meteorology that is, meteorological data that is representative of the site. There is a choice that they can make to use generic meteorology if it's shown bounding from the site.

So the first going-in assumption is that you're characterizing the site in these analyses, but there are conservative assumptions that you can make as far as the population distribution to help you with the LMP process.

CHAIR ROBERTS: Okay. Thanks. I was trying to understand that first sub-bullet. The intent then is to start with the uniform population distribution and then show for each side that that's conservative?

CHAIR ROBERTS: Okay. Thank you.

MS. HART: Next slide, please. So we just talked about the meteorological data. The objective of the data is to, you know, to characterize the site. MACCS does require input, wind speed, direction, stability, category, rate, and mixing height that is representative of the weather conditions at the power plant over the most limiting year. We do a year's worth of hourly data to run the model in MACCS. And as I just stated, the topical report states that, in lieu of that, they may have this generic meteorological data file based on the Electric Power Research Institute's Advanced Light Water Reactor Utility Requirements document if the data is shown to be conservatively representative of the site.

We did ask a question about that. The NRC has previously found the URD data to be acceptable for use in design, you know, phase for applicants -- not for applicants -- for designers to use in helping design their facilities. We did ask what they meant by conservatively representative of the site, and the only thing that you can really do is do a calculation to determine what the consequences are.

And so, you know, we will look at that in implementation if they're using the generic data, you know; and if they show a reasonable representative amount of the events are bounded by the generic data, then that would fulfill that --

MEMBER HALNON: Michelle, this is Greg. This is another example of where Dave was going earlier with how much is needed for CP. It's clear the OL is going to have to have site-specific data for a number of years to be able to show it's within the envelope, and that's the intent here, I assume, is the URD is okay for now but it's not going to hack it for an OL.

MS. HART: Yes. We, the staff, think it's much more reasonable to use this generic data for a construction permit because you do not have the final design.

I think, you know, the methodology is not bifurcated in that way. We did not necessarily definitively say that they couldn't show in the OL that it was acceptable to use the generic data, you know, to use it similar to, you know, you would think of, like, for a design certification, you show that your site characteristics are within what you had assumed in your generic analysis. You know, it remains to be seen when we get to the operating license if it's acceptable or not.

MEMBER HALNON: I mean, it's sensible from the standpoint of when you're looking at a first of a kind versus nth of a kind. Again, you're going to try to do a bounding analysis. If it's within that envelope, you can move on. If not, then you have to have a additional analysis show it's okay.

MS. HART: And I think, you know, unlike with when you're developing chi over q's using ARCON or PAVAN, things like that, it's harder to tell that your site characteristic chi over q's are within the chi over q's that you used in your generic analysis using MACCS with a set of, you know -- your yearly, hourly year-long data is hard to tell if it's conservative or not.

CHAIR ROBERTS: Vicki had her hand up.

MEMBER BIER: Yes. If I can follow up just to make sure I understand. So it sounds like this generic analysis might be consistent with a design being acceptable at many sites and being able to be demonstrated to be acceptable at many sites but, presumably, there are some where, even if the generic looked okay, there might be kind of a unique combination of wind direction and population density that means that some sites would not be able to demonstrate acceptable consequences. Is that correct?

MS. HART: Yes. I could see that as being a situation.

MEMBER BIER: Okay. Just trying to make sure. Thanks.

MS. HART: Okay. Next slide, please. Our review determined that they did identify the specific meteorological data that's required to run the code to characterize atmospheric dispersion for the site and that the use of the generic data is acceptable if it's shown to be conservatively representative of the site and that the use of the URD generic meteorological data is similar to the uses described in the URD with respect to completeness of the data set.

We did apply Limitation and Condition 1 or imposed it, in part, to ensure that the use of the URD generic meteorological data is limited to sites within the contiguous U.S. consistent with the basis for the data.

Our approval does not constitute approval of the site's use of generic data instead of site-specific data in future analyses. When addressing relevant regulations, such as 50.34, the siting analysis, or the safety analysis off-site consequence analysis 25 rem requirement, applicants referencing this topical report should consider how this methodology may need to incorporate additional information in order to satisfy the regulatory requirements, and we also did find the use of random weather sampling to assess consequence uncertainty due to weather conditions is acceptable because it's consistent with guidance on radiological consequence analysis for PRA.

CHAIR ROBERTS: I was just curious why you chose that limitation and condition instead of the second sub-bullet. It seems like, if you read the second sub-bullet, it doesn't matter where the site is, as long as it shows that the -- you were at the conservative for that site.

MS. HART: So the URD data was developed based on the lower 48 states. So if they were to locate in Alaska, it's not entirely sure that the data would apply, or if it was located in Canada or some other location. And so, because the basis for the URD data was not for those types of locations, out of an amount of caution, we wanted them to justify whether it was still acceptable for their specific site.

CHAIR ROBERTS: Okay. I don't want to speak for the applicant, but it seems like, if it's got a conservative generic environment, it would seem like a pretty good starting point, as long as you justify it's conservative, instead of having to come to a different data source for a generic environment. Just an observation. It seems like that second sub-bullet is just as good or better than the limitation and condition because it requires demonstrating that the data is conservative for that site.

Okay. Yes, this works, too.

MS. HART: Thank you. Next slide, please. So the next topic is the atmospheric transport and diffusion analysis. So this is, you know, the MACCS code atmospheric dispersion modeling is acceptable because it's consistent with the implementation in NRC-developed atmospheric dispersion codes used in reactor licensing analyses, as well as the technical guidance for MACCS. That's written in NUREG-CR-7270, and it considers things such as the characteristics of the area and distance ranges under consideration, near field effects such as elevated releases of reactor material, building wake effects, plume meander, plume rise, and plume deposition based on wet and dry deposition.

Next slide, please. Our review determined that the use of the Gaussian plume segment model in MACCS is acceptable because it's based on the guidance contained in Reg Guide 1.145 and Reg Guide 1.249, which are used in the licensing of power reactors. Those are the guidance that talk about use of PAVAN and ARCON or off-site consequence analysis. The LBE EM use of the MACCS CHRONC module to model long-term exposure to radionuclides deposited on the ground is appropriate because it models the effects of weathering on the ground, contamination concentration, as well as resuspension of the radionuclides to the atmosphere as consistent with risk analyses using the MACCS code as described in NUREG-CR-7270, which is guidance on use of the MACCS code, and also addresses the need for calculating the latent cancer fatality QHO that you have to have that 50-year consequence.

Limitation and Condition 1 is supposed, in part, to also ensure that the use of the topical report is limited to sites within the contiguous U.S. because of the atmospheric dispersion models, the Gaussian plume models, are based on weather conditions that are expected in the contiguous U.S. So Limitation and Condition 1 has two parts: limitation of the data to the contiguous U.S. and limitation of the use of the atmospheric dispersion model to the contiguous U.S.

Next slide, please.

MEMBER MARTIN: I'll jump in here real quick. The Reg Guide 1.145 is pretty old. A lot of new in this design and a lot has been learned in 45 years since that reg guide came out. And, of course, here, they're using MACCS. It seems like it would be appropriate to kind of go back and relook at the bases for Reg Guide 1.145 in the context of maybe the unique setting that we find ourselves here in 2025.

MS. HART: So I will say Reg Guide 1.249 has looked, again, at off-site consequence analysis and uses the models that are appropriate for nearfield modeling. You can use ARCON to do the off-site consequence analysis now in a similar way.

As with all of our reg guides, we do continue to look at them to determine if there's any updates that are needed. Unfortunately, I am not a meteorologist. You know, that's not my area of expertise. I don't know if we have any of the meteorologists online available to speak to any plans for an update of Reg Guide 1.145, but I will say, for regulatory purposes, the use of the Gaussian plume model and the information in that guide continues to be reasonable for use for regulatory purposes.

MEMBER MARTIN: And I asked a question earlier about the whole spectrum of frequency consequences. The original vision was mostly just for DBAs. That would be something new today under NEI 1804 model that would not necessarily have been thought of when the reg guide, at least 1.145, was set up.

MS. HART: So, of course, Reg Guide 1.145 does not do the weather trials. It doesn't do the same kind of uncertainty propagation that you can do with MACCS, and MACCS is an appropriate tool to do that.

And so I think, you know, I don't know if we would consider putting that kind of information in Reg Guide 1.145. I saw that one of the staff meteorologists, Mike Mazaika, who was on this review, did raise his hand. So, Mike, did you have anything that you wanted to add to this discussion?

MR. MAZAIKA: Yes. Can you hear my audio?

MS. HART: Yes.

MR. MAZAIKA: Okay. 1.145 and the PAVAN model is for design basis assessments and is conservative in that respect, and there are some fundamental differences between what MACCS does, as Michelle said, and what the PAVAN code does.

Right now, the model itself is being integrated under the RAMP website that NRC maintains, but we are trying to get the code as it exists now implemented into RAMP, into that code consolidation. And we are looking in the future to upgrade the model, but as to when that's going to occur I cannot really tell. I don't know if that answers your question.

MEMBER MARTIN: Well, maybe I'm going to key on the word update. What updates are being considered?

MR. MAZAIKA: At this point, it's real up in the air. Some of the provisions that are not in PAVAN would be plume rise, plume rise both for buoyancy and momentum. And that may be an important consideration when you're located in a climate like Alaska, and that all depends on the temperature of any kind of releases, either accident or another model, XOQDOQ, which is for long-term averages which does include plume-rise algorithms because it may affect where the plume is transported. A lot of the sites have short boundaries. Typically, what we've heard are 400 meters downwind from a release point, and the maximum impact may occur off-site.

So plume rise function would be one. What we learned from the Fukushima experience is washout was potentially important at a given location, and, right now, PAVAN is only configured to account for dry deposition. And I noted on one of their earlier slides that undepleted, undecayed chi over q was being used, which would be a conservative approach.

So those are the two main things that are being looked at, and the other thing that I think is being implemented in the consolidation of the codes would be to run PAVAN, which is now run under joint frequency distribution -- it's basically a statistical measure of whatever the period of record of meteorological data is -- as opposed to using hourly data. And a change underway is to use hourly meteorological data.

MEMBER MARTIN: As you were talking, I was thinking about maybe one unique scenario that you might have. You might have a situation where there is a fire, a sodium fire, and it would be accompanying any release aerosols generated from the fire itself. That actually might be beneficial; I don't know. But have people thought about the uniqueness about, you know, sodium-cooled fast reactor and releases, you know, because of scenarios that might be anticipated there, as opposed to light water reactors.

MR. MAZAIKA: Yes. I agree that would be

another topic, and one of the things, at least from my involvement so far, is trying to get a handle on what the temperature of potential accidental or routine releases would be. And, specifically, it's related to what Michelle mentioned about Limitation and Condition No. 1. There's a lot of talk about potential deployments in regions that are subject to extreme and cold persistent conditions, like Alaska, and that could have an effect on dispersion. And the models itself, as Michelle mentioned were developed based on field studies in the lower 48 states, and we're not quite sure what the dispersion conditions would necessarily be.

Another aspect in Alaska is, depending on your location, a split analysis may be necessary because it reaches 90 degrees in some portions of Alaska at certain times of the year. So when you're looking at a longer-term average, a concentration or a chi over q coming out of an analysis, it may have two components to it: dispersion conditions potentially under extreme cold conditions and dispersion under typical summer conditions that we might see in the lower 48.

MEMBER MARTIN: Thank you.

MR. MAZAIKA: You're welcome.

MEMBER PALMTAG: This is Scott Palmtag. Sorry. I've been sitting here thinking about what generic atmosphere conditions mean for Kemmerer. I think it's a specific operating license for Kemmerer, sorry, not a generic license. And I would argue that Kemmerer probably is not a generic atmosphere. In the lower 48, it's very windy and it's also very high altitudes.

But the operating license is going to be for the specific Kemmerer data, right? Is that correct?

MS. HART: So the construction permit for Kemmerer, yes, they do characterize the site.

MEMBER PALMTAG: When we go to the operating license --

MS. HART: We'll get to the operating license. That remains to be seen. This topical report is not just for Kemmerer, though, of course. It's a methodology that could be used at any site.

MEMBER PALMTAG: The Kemmerer probably is not generic it's just -- very high elevation rate thing. And then also you mentioned Alaska. I'm just wondering if a better approach would be to let the applicant decide what to use and with that, the risk that, when they get to the operating license, it will have to be for the site specific.

For example, if they want to use some generic Kemmerer data, they'd be allowed to do it, which might be more representative than these generic lower-48 state atmospheric data. In the end, the operating license would be specific site. That would be the same thing for Alaska. Let the applicant use whatever they want.

MS. HART: I mean the applicant can use whatever they want anyway. I think the methodology report, the topical report, does not identify that as a potential pathway. But if an applicant further down the road wanted to say we're just going to re-use Kemmerer's analysis, then we would have to take a look at that. It wouldn't be part of this methodology, but it would be subject to review at the time.

MEMBER PALMTAG: Yes. I'm just thinking the limitations you put on that are trying to specify the generic atmospheric conditions they used, and maybe that's not the best approach. Maybe it's the best approach as to let the applicant decide what's closest.

MS. HART: Yes. So the methodology says to use site-specific information, but, in lieu of that, you could use the generic. So the generic is not necessarily the going-in position, and so this limitation and condition is only related to if you choose to use the generic data.

MEMBER PALMTAG: I understand, but maybe, instead of saying use the generic data, let them decide on their own. Just a thought. Why specify --

MS. HART: Well, we kind of have to address what they put in the topical report.

MEMBER PALMTAG: In the end, the operating license is going to be on the site specific, so it's going to be risk to the applicant.

MS. HART: I mean, the methodology and the approval that we have right now with, say, if they can show that the generic is bounding for the site even in the operating license. Now, how they go about that is to be determined, but that wouldn't necessarily be inappropriate, as long as they have met data that is representative of their site and characterizes their site, whether it's site specific from a tower on their site or shown as being representative through some other means. And I know it's all very kind of theoretical.

MEMBER PETTI: I don't know what way you're going, Scott. The utility guides put out -- generic is not the right word. It is a bounding set of meteorology that will work across the U.S. So it probably bounds Kemmerer.

MEMBER PALMTAG: It seems like it could be a little too restrictive. It's just a thought. I mean, I'm not going to argue, but it seems like you could probably predict data a little better than using a lower generic 48 conditions.

MEMBER PETTI: Sure. But, again, the topical report is for any -- beyond Kemmerer potentially.

MEMBER PALMTAG: But the limitation conditions, the way I understand them, were use generic data or site-specific data. Maybe I misunderstood that.

MS. HART: So the limitation and condition is addressing, as far as the met data, is addressing the fact that they said, in lieu of site-specific data, to use the specific URD data, and the URD data was based on the lower 48 states. So that's where the contiguous U.S. limitation comes from. It's referring to the basis for the URD data. It's not outside of that consideration.

MEMBER HALNON: But regardless of what this uses, any site-specific allele is going to have to be either bounded by this or its own analysis. So that's just the way --

MEMBER PALMTAG: Another consideration would be site-specific generic data or predicted --

MEMBER HALNON: I don't know what site-specific generic means.

(Simultaneous speaking.)

CHAIR ROBERTS: I want to observe for the record that our consultant, Dennis Bley, has joined us and he has a question. Go ahead, Dennis.

DR. BLEY: Yes. Just a quick thing, though. I was trying to raise my hand, and it never looked like it worked.

I admit I never thought about this. I'm a little confused because bounding meteorology is a pretty wooly idea. Every scenario, population distribution, et cetera, could make a different meteorology worse than something you're looking at. That seems really hard to define a bounding meteorology or to claim that one is bounding for your site, unless you really look at every scenario coming out of the system.

Have you guys thought about that much, Michelle?

MS. HART: So I don't disagree with that idea. I think, you know, going in with the idea that, you know, EPRI developed this set of site information that people can use to help them design their reactors. It doesn't seem like it's an inappropriate use for, you know, determining your design through the LMP process or helping you evaluate your design through the LMP process. It's a different matter, and that's what that one, you know, saying that our approval does not show that they meet the regulations necessarily, you know. It's different when you're talking about meeting, like, the siting requirements. You know, have you appropriately shown that.

DR. BLEY: Yes, I agree with you on the design side. But you said something earlier that, when they come in for a license, they can use a bounding meteorology, and I really have trouble seeing how you could decide a meteorology is bounding for your site and the range of accidents you're looking at. That just seems kind of tough to do.

MS. HART: Right. And it's contingent on them showing that it's bounding for their site, and so that's, you know, it's still a little vague how they would do that. But, you know, if they can do that, it's something that we could evaluate at the time.

And I did want to address something about the source terms. As far as the MACCS code, you can put in the heat to help you with the buoyancy calculation, but there's no ambient, you can't change the ambient temperature. So it doesn't really do, like, the atmospheric temperature, but you can put in the heat load of the release if you have that information from the source term or other methodology.

Anymore questions? Okay. Next slide. So the protective action analysis, this is something that's discussed in the PRA standard. As far as the uses for the LMP, not modeling protective actions, such as evacuation or sheltering, is conservative so that you get the higher doses to help you with your LMP process. Their EM does conservatively model no protective actions. In other words, that standard evenly-distributed population assumption, they don't move them, and it's used to calculate dose of the EAB and for the individual risk of early fatality.

We did determine that the modeling for short-term exposure without credit for protective actions is acceptable because it results in conservative test results.

Next slide, please. The EM models the intermediate- and long-term phase protective actions, such as land decontamination and condemnation based on dose levels from the EPA, protective action guides, the PAGs, to evaluate individual risk of latent cancer from long-term exposure, that 50-year exposure, to radionuclides deposited on the ground. And we determined that that modeling and protective actions for the long-term exposure is acceptable because it's consistent with the recommendations for the use of the MACCS code for risk analyses and NUREG-CR-7270 and is also consistent with the intermediate-phase PAGs that you would use from the EPA.

We will evaluate the modeling of the dose reduction factors associated with the occupancy of structures or vehicles, which are not described in the EM, in our review of the analysis supporting a license application that references the topical report. So they didn't give specific guidance on reduction factors that you should use for that purpose.

Next slide, please. The next topic is dosimetry. You know, our review of the topical report information determined that the information on organs of risk that you use in these analyses is acceptable because it's consistent with reactor risk analyses using the MACCS code as described in NUREG-CR-7270, as well as the guidance in Reg Guide 1.183 on use of dose conversion factors from Federal Guidance Reports 11 and 12 to calculate TEDE.

The information on the calculation of risk of early fatality and risk of latent cancer fatality, including parameter values listed in the topical report tables, is acceptable because it's consistent with reactor risk analyses using MACCS code. The method for calculating dose is acceptable because all relevant short-term and long-term exposure pathways were identified and calculated considering inhalation dose, cloud shine, and ground shine consistent with guidance in Reg Guide 1.183 for estimating TEDE. Calculation for the risk metrics is acceptable because it's based on FGR 13, which is a recognized information source developed by the EPA as a resource for the federal government and reflects age- and gender-averaged adult population. And the modeling of exposure periods is acceptable because it's consistent with the description in NEI 1804 for the dose quantities to be compared to the LMP frequency consequence target, the 30 days, quantitative health objective figures of merit for early fatality risk, and latent cancer fatality risk. And it's reasonable for the evaluation of cumulative probability per plant year of exceeding 100 millirem TEDE at the site boundary as required by the LMP.

Next slide, please. The next topics is

health effects analysis. The PRA standard states the objectives of the health effects analysis is to assess the risk of latent health effects, either fatal or non-fatal, both arising from acute and chronic exposure. We determined that the evaluation of health effects is appropriate because the list of cancer fatality sites in the human body is consistent with FGR 13 and the list of early fatality health effects is consistent with those identified in NRC reactor risk studies with consequence analyses, such as NUREG-1158, as well as the guidance on use of MACCS in NUREG-CR-7270.

Next slide, please. The PRA standard also goes into economic factors. The LMP methodology does not use economic factors or cost-benefit analysis to determine events classified as SSCs or evaluate the adequacy of defense-in-depth, and so we found that the discussion in the topical report was consistent with the requirements in the LMP or the needs for LMP.

Next slide, please. Conditional consequence quantification. The use of MACCS in the LBE EM is consistent for the purposes for which MACCS was developed, as well as within the limits of the code's applicabilities. MACCS isn't a reasonable code to use for this purpose. The MACCS model inputs and accompanying data files and specifications are acceptable for use in the LBE EM because they are consistent with the sample problem supplied with MACCS and NUREG-CR-7270. On certain parameters, they contribute significantly to radiological consequences. For analyzed conservatively, bounding values were prescribed in the topical report. And the weather sampling approach is acceptable because it addresses the uncertainty in the weather in combination with variability and meteorological conditions consistent with our approach in a probabilistic consequence analysis.

To go more precisely to the parameter uncertainty for this particular analysis, for the most part, the topical report has a list of how they're going to treat the different parameters, and a lot of them, they are going to make conservative assumptions or they're going to do sensitivity analyses to pull information that would work for the specific event that they're looking at. So there's no one prescribed or not even a set of prescribed uncertainty distributions or anything like that in the topical report. And we determined that that was acceptable and we could evaluate the specific evaluation that they have during the implementation review.

Next slide, please. So in conclusion, for the licensing basis event evaluation model, the NRC staff feels that the topical report methodology provides estimates of the radiological consequences for the licensing basis events for use in the LMP methodology consistent with the non-light water reactor radiological consequence analysis PRA elements. We also found that the consequence analysis results, when used in the LMP, are sufficient to address the analysis requirements in the regulation. And the identification of MACCS to evaluate PRA consequences is appropriate because it's an NRC-developed widely-used PRA analytical tool specific to consequence analysis.

Are there any additional questions on the licensing basis event evaluation model? So now I will turn it over to Zach Gran to talk about the design basis accident evaluation model.

MR. GRAN: Thanks, Michelle.

Again, my name is Zach Gran and I'm a reactor scientist and technical reviewer in NRR. I will be presenting the next couple of slides for DBA and control room habitability.

The objective of the Design Basis Accident Evaluation Model is to describe the methodology that would be used by a future applicant to calculate the highest TEDE dose received over any two-hour period by a receptor on the exclusionary boundary and to calculate the 30-day TEDE dose received by a receptor at the Low Population Zone boundary.

The dose analysis considers contributions due to inhalation and submersion doses described in Reg Guide 1.183. On this slide, we note that the dose criteria is just for comparison.

The NRC staff determined that the Design Basis Accident Evaluation Model performs calculations consistent with the guidance or states that they will perform calculations consistent with the guidance.

And we did this by reviewing the RRCAT Computer Code Manuals during our audits. From the audits, we kind of determined the Radiological Consequence Analysis assumptions and inputs to be consistent with how would understand the calculation or do this calculation.

Next slide, please.

The objective of the Control Room Habitability Evaluation Model is to determine the consequences required to demonstrate habitability in the control room, in conformance with the Natrium PDC 19, which states that "Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without the personnel receiving radiation exposures in excess of 5 TEDE for the duration of the incident."

The specific dose consequences calculated in the Control Room Habitability Evaluation Model are the 30-day TEDE dose received by a control room receptor, considering inhalation, submersion, and gamma shine from the radionuclides external to the control room, built up on filtration equipment and held in a compartment before release to the environment.

Next slide, please.

The NRC staff's review determined that the methods to calculate inhalation and submersion doses are consistent with the methods described by the Design Basis Accident Evaluation Model; that the Control Room Habitability Evaluation Model performs calculations consistent with Reg Guide 1.183.

In addition, the Control Room Habitability Evaluation Model describes the proprietary method for calculating shine dose received by control room operators, which the staff determined is acceptable because the described method produces an integrated control room dose that includes the inhalation, submersion, and shine dose pathways.

The NRC staff will evaluate the acceptability of the specific methods to calculate release-specific radiological source terms, control room atmospheric dispersion factors, and modeling of the control room used as input to the Control Room Habitability Consequence Analysis during the review of an application that references and implements this evaluation model.

This wraps up the few slides that I had on Design Basis Accident Evaluation Models. Unless there are any questions, I'll pass it back to Michelle.

MS. HART: Okay. So, they did provide an appendix in the Topical Report about adapting the licensing basis event methodology for EPZ sizing. The Emergency Planning Zone Sizing Methodology Topical Report does require the two doses that they discussed earlier in TerraPower's presentation. And for the most part, they've just adjusted the timing, so that they can get the right dose results.

We found that acceptable, and the actual calculation of the requirements for the Emergency Planning Zone sizing is in that methodology. It's not part of this methodology. This passes as input to that methodology.

Next slide, please.

So now, we'll talk about the limitations and conditions. We had two limitations and conditions in this Topical Report.

And so, the first one is that application of the methodology with respect to the described deterministic and probability-based atmospheric dispersion modeling analysis and use of generic radiological data is limited to sites within the contiguous U.S., unless technical justification for the applicability is provided.

And the second is that the conclusions reached in this SE are not valid in a process other than that described in NEI 18-04 used to perform the Natrium Safety Analysis.

That second limitation and condition was applied because, you know, the Topical Report was written in that context. So, it's not to say that they couldn't use similar methods for other purposes, but considering that the Topical Report was written for this purpose, we thought it was appropriate to apply that as a limitation and condition.

Are there any questions?

MEMBER MARTIN: Earlier I asked TerraPower about the V&V for their internally developed RRCAT

Code. What did you all do as far as the due diligence on that? Mostly, reviewing their QA program? Did you get into the weeds a little bit on their actual test cases and such?

MS. HART: We did not get into the weeds. We did have the opportunity to look at the user manual to see what was included in RRCAT and looked at some of their comparisons to use of the RADTRAD Code, which we do understand because it was developed for us. We didn't go deep into detail. We did note that they said it's part of their QA program.

CHAIR ROBERTS: Okay. Any other questions from my members or consultants for the staff on this Topical Report?

MS. HART: I guess I did have one more slide. It's just the overall conclusions. We did find it acceptable. I don't know that I need to go into more detail about that.

MEMBER MARTIN: Do you have any RAIs on this?

MS. HART: We did not have RAIs. We did do an audit and we had several questions in the audit.

We did have a lot of discussion with them on the use of the MACCS code because this is the first time, as we talked about earlier, that anybody has used the MACCS code, and there are some particularities to how you use the code and understanding the specific inputs and assumptions. And their Methodology Report did go into that in some detail. And so, we have a lot of discussions about that.

We did not have quite as many discussions on the non-proprietary, you know, the parts of the DBA and Control Room Habitability Analysis, that were not due. We'll just put it that way.

MEMBER HALNON: Michelle, the MACCS code was what you all used, right? If I remember, you said it was developed for the NRC to use. So, you use that to verify other calculational methods coming in to verify that it's within the bounds of reason, I guess. So, I guess the question is, how --

MS. HART: How have we used MACCS? So, in the past, we have used MACCS for reactor safety studies, such as SOARCA. We have done some confirmatory analysis when we look at the environmental reviews for power reactors.

MEMBER HALNON: Yes. So not --

MS. HART: But we have not used it in licensing before, no.

MEMBER HALNON: So, how do you do a

confirmatory analysis to make sure that it's working in this situation then?

MS. HART: So, in this situation -- and I have not performed a confirmatory analysis; I will state that upfront. But given a source term, given information -- and we may have to find that through audit -- given a source term and given the met data, we would make similar choices that they would make. We may make different choices. We may make some assumptions about parameterization of, you know, like aerosol sizes or something like that, and maybe do it differently than they had -- would be a potential way to do it.

I have not made a determination of certainly not -- I don't think I'm going to do it for the Construction Permit, but we are not done with that review yet.

MEMBER HALNON: It just seems that using the same code and just changing inputs, whatever output is going to -- it's not the confirmatory analysis --

MS. HART: User choices can make a bigger difference than you think. And so, you can do some uncertainty-type or sensitive-type analyses on the choices that the user can make. and I even do that now with, like, the RADTRAD code. If the licensee or applicant uses the RADTRAD code, I can take the information from the FSAR or PSAR and interpret it myself and put in something similar.

I think, you know, the thing that's harder to recreate on my side necessarily is, like, the source term itself. You know, you have to take that -- or my first going-in position would be to take that as a given, unless there's something that we develop ourselves. So, we have not done that.

MEMBER HALNON: Okay. So, you may have to develop a scheme to make sure that you're satisfied with the codes?

MS. HART: Right.

MEMBER HALNON: Okay. All right.

MS. HART: And to a certain degree, some of the -- at least my use of a confirmatory analysis, it's just to see if I understand the words that they put on the page and to understand the design and how they've modeled releases from the design.

MEMBER HALNON: Okay. That's fair enough. Thank you.

CHAIR ROBERTS: If there are no more questions from members or consultants, we're about 30 minutes behind. It's my thought to take a break now, 10 minutes, instead of 15 minutes, and come back at 10:20 Eastern with the Applicant presenting the other Topical Report on source term.

With that, we are in recess until 10:20 Eastern.

(Whereupon, at 10:10 a.m., the foregoing matter went off the record and went back on the record at 10:20 a.m.)

CHAIR ROBERTS: All right. It is now 10:20 Eastern and we resume the meeting with TerraPower presenting on the mechanistic source term methodology.

MR. SINODIS: Okay. Thank you.

Good morning. My name is Joe Sinodis. I'm an engineer in the Source Term Methods and Analysis Group at TerraPower. Appearing today with me, we also have Chris Forrest and Jong Chang helping assist.

Next slide, please.

So today, we'll be providing an introduction and high-level overview of the source term methodology for Natrium.

Topical Report NAT-9392, which was submitted, describes the development of a Mechanistic Source Term Evaluation Model utilized for the Natrium

Construction Permit Application.

The objective of the source term is to provide input for evaluating the radiological consequences of quantified events. And certain aspects of the evaluation model remain in development, as noted in the Topical Report.

It is also acknowledged that information from ongoing and future development actions will be completed prior to using the EM in an operating license application. So, it is the intention to submit an update to the Topical Report for the OLA.

The EM development generally adheres to Reg Guide 1.203, using that as a framework, insofar as it is applicable to the nature and design for source term. We can also use generic TerraPower methodology development guidance.

So, with that in-depth process, of course, it is 20 steps and four elements. We've talked about staffing requirements for the EM capability, developing the assessment base, developing the EM itself, and assessing the EM adequacy.

MEMBER PETTI: I just had a question here. I tend to think of 1.183 as the starting point for source term. And bringing in 1.203, what might call novel; one might call it, you know, an albatross in terms of the requirements that 1.203 bring to this area, which has not historically been done. You know, if you look up LWR stuff, it's very prescriptive and you follow 1.183. You do it, even the stuff we heard this morning. You know, why did you guys decide to bring in 1.203, given, I'll call it, "the baggage"? I mean, it's a significant resource-intensive exercise.

MR. SINODIS: Yes, thank you.

Jong, do you have any background on this?

MR. CHANG: Yes. This is Jong Chang. I'm a manager at TerraPower.

So, the reason we kind of combined, like, two steps with Reg Guide 1.203 is a typical system transient type of, like, a methodology development process.

And also, Dr. Petti, you mentioned Regulatory Guide 1.183 has several steps. When EPRI could be coming in with different and prescriptive, like, LWR source term development, there are steps we can follow.

So, we found, like, a generic system steps. I believe there's five steps. So, that gives like guidance. However, when we developed the mechanistic source term, the mechanistic source term starts from, typically, like upstream of like a neutronics core design, and then, system design, et cetera.

So, then, that information is not clear in the Regulatory Guide 1.183. So, that's why we're kind of combining kind of a historic, like, system development aspect of it, and then, the other side, like how we bridge between mechanistic source term to develop it like, from that area. So, then, that's why we put it into kind of Reg Guide 1.203 as an industry best practice. And this has worked for many decades. I think that's why we did that.

It has, like, a basis and it has, like, a typical these are some of the steps, but we are not compliant with each individual step, but we take it as generic items.

MEMBER PETTI: Okay. So, it's more guidance, the intent, instead of the letter of the law? Because there's a lot of steps in there that I just go, okay, how are you going to validate some of this stuff? So, you're going to use it in sort of a best practice sense?

MR. SINODIS: Yes, I think that's a correct characterization. Yes.

MEMBER PETTI: Okay. Because the other

thing, we're not there, but using the multiple computer codes inside the evaluation methodology for source term is also new, I think, and will present its own challenges going forward.

MR. SINODIS: Okay. Thanks.

MR. FORREST: Yes, this is Chris Forrest with TerraPower.

Just another point related to that that I think is important to say upfront. Of course, the application of Reg Guide 1.203 is very specific to DBA analysis. However, it's worth acknowledging that our source term evaluation model here is intended to cover all of our LBEs, so non-DBA LBEs as well as DBA LBEs.

That's also another reason why we're using it as guidance and not strictly following it, because we're not necessarily doing those most conservative analyses on our non-DBA LBEs.

MEMBER PETTI: You know, you need flexibility. There's enough novelty here that flexibility is going to be, I think, useful as you go forward.

Thanks.

MR. SINODIS: Next slide.

So, the intended applications Chris just touched on for the source term EM are normal operation of the Natrium plant; system leakage scenarios; licensing basis events and other quantified events, including AOOs, DBEs, the subset of DBAs, and BDBEs. It also informs the Emergency Planning Zone sizing and will be used for potential dose mapping for equipment qualification evaluations.

So, the Topical Report is sort of structured following the Reg Guide 1.203 sort of outline, and the presentation is here as well.

So, defining source term EM capabilities. So, the source term EM will apply to all transient classes that can result in fuel failure.

A phenomena identification ranking table process was conducted to identify and rank key phenomena anticipated for the mechanistic source term. And that was performed for three representative events: unprotected loss of flow, fuel-handling accident, and a sodium processing system leak. Then, those were combined together to identify what we considered high-risk phenomena.

And with the PIRT process, we looked at two primary figures of merit. That's inhalation dose potential and submersion dose potential. And we included that word "potential" just as a delineator. As the source term EM is not calculating the dose itself, that's done by the radiological consequences EM. The source term is an input to the downstream EM.

The Topical Report, we also discussed a little bit about functional containment. As has been talked about previously, Natrium is adopting the functional containment definition from SECY-18-0096, which defines "functional containment" as a barrier or set of barriers that effectively limits transport of radioactive material to the environment.

And then, we have two major barrier types that are defined by function.

The primary barrier, which would be a system, structure, or component that performs radionuclide retention function necessary to keep offsite DBA doses within regulatory limits or keep the DBE consequences from exceeding the frequency consequence targets.

Then, we have the enveloping barriers, which are those SSCs that provide backup radionuclide retention function following failure or breach of an associated primary barrier.

And also, the source term EM is used to establish the performance criteria for the various barrier types.

MEMBER PETTI: So, can you give us an

example of the primary versus enveloping in the design?

MR. SINODIS: Yes. I know we will have some of that in the --

MEMBER PETTI: Closed?

MR. SINODIS: -- closed session. Yes, and that might be a better place, but thank you.

CHAIR ROBERTS: I wonder if you can clarify a little bit more in this open session.

We had a pretty extensive discussion where we had the meeting on the Principal Design Criteria Topical Report as to why a lot of the Reg Guide 1.242 PDCs were being deleted in favor of the HTGR-type catchall functional containment. And we documented that what you are doing appears to be consistent with prior SFRs in terms of the physical barriers that are provided in the containment or in the design to meet a containment function.

And so, it appeared to us after our discussions that the resulting approach to containment would be essentially the same as prior sodium fast reactors. Would you agree with that or is there some degree of -- I don't want to use the word "compromise" -- but some differences from prior SFRs, based on applying the term "functional containment" versus having all the individual criteria?

MR. SINODIS: Thank you for the question.

Chris or Jong?

MR. FORREST: Sure. Chris Forrest from TerraPower.

I think the discussion from the PDC meetings are well-documented certainly. And I know that Eric Williams was here and presented a number of points where Natrium does differ from historical SFR designs.

Our approach here in our functional containment development does follow the structure outlined in SECY-18-0096, which provides a framework for establishing performance criteria. And that's how we're going about identifying and establishing that performance against those barriers.

CHAIR ROBERTS: All right. But in comparison to prior SFRs -- but again, recognizing we have more details in the closed presentation -- having primary and enveloping barriers implies that you've got physical structures that are there to at least partially serve the purpose of retaining radionuclides.

And you've got performance criteria. Your last bullet there says that it goes to the subsystem;

that there's testing required periodically. So again, would it be fair to say that the overall approach to containment is, essentially, the same as prior SFRs, even if it's analyzed using functional containment criteria that are more performance-oriented?

MR. FORREST: I think when you look at the specifics of the designs and comparing the designs, you'll find that the SSCs differ.

What's presented on the slide here is to sort of demonstrate at a high level that we have graded performance, depending on the SSC, its location, and its function that it's serving.

These two sub-bullets here provide an example of, you know, an SSC that's a primary one that's needed to succeed in keeping doses within DBA limits. That, of course, is going to be a safety-related barrier with appropriate surveillance and testing applied to it.

These enveloping barriers serve a slightly different function and, of course, would have different criteria assigned to them.

CHAIR ROBERTS: Can you provide an example of that? So, you have an enveloping barrier that's not defined as a primary barrier. So, it's not safety-related. So, what would that mean in terms of what would you not do in terms of either design quality or testing of that barrier, because you're calling it non-safety?

MR. FORREST: Sure. So, I think a fairly simple example of that is a primary barrier, you know, would be a low-leakage-type barrier that we could pressure test at some frequency, at some maintenance frequency.

An enveloping barrier would be some other sort of structure, such as a building structure, that's expected to not be affected by an initiating event and have some performance associated with it.

Of course, we can get into a little bit more specifics on SSCs in the closed session.

CHAIR ROBERTS: Yes. Okay. Thanks.

MEMBER HALNON: Yes, this is Greg.

Would an enveloping system pertain to, like, a HVAC system of filtration or something to that effect?

The reason I'm asking is I understand that some of it is proprietary, but we're also in a public forum right now. And we heard a comment yesterday that there's lack of information, at least as being felt by some people in the public.

If there's some specific examples, even if it's generic, that you can give folks a sense of what you're talking about -- and I think that was the sense of Dave's question and Tom's. You know, give some sense of what structure?

I mean, with primary, we all use the same containment, you know, pressurize it to 60 pounds every 10-15 years and everything is great. This is different.

And even if you go back to the previous SFRs, some sense of what we're talking about here, because this is the barrier that we're concerned about from the standpoint of offsite public dose.

So, when you say it's enveloping, a building or something, would that include, obviously, a leak tightness criteria, plus a ventilation system? Try to give some kind of word picture to what people are hearing.

MR. SINODIS: Sure. And the example of an enveloping barrier is generally going to look like a compartment that in some cases -- or a compartment that would have an appropriate leakage criteria as defined, you know, as demonstrated by or dictated by our Safety Analysis. So, if our Safety Analysis is showing that an enveloping barrier requires a certain performance, as described here, you know, provide that

--

MEMBER HALNON: Given a failure of the primary --

MR. SINODIS: Given failure of the primary, to provide that backup function.

MEMBER HALNON: Okay. So, that will be evident when the design comes out. It will be in the FSAR, probably the operating license, tech specs, if necessary?

MR. SINODIS: Correct.

MEMBER HALNON: So, it's not going to be something that people won't have confidence in. It will be well-adjudicated as we go through the process to get an operating license?

MR. SINODIS: Right. That's correct.

MEMBER HALNON: Thank you. Okay. Thank you.

MEMBER MARTIN: I think just to pound home the messages, your enveloping barriers are largely non-safety. That is the real departure here, right? Because the enveloping barrier on traditional LWRs is the containment. Containment is safety-related.

Now, I mean, in my personal opinion, although I think there are others that are like-minded, it's that the role of containment is really to cover kind of the residual risk. We understand a lot of risks. We don't understand all the risks. There remain unknowns that we may never see and some of them that, of course, could happen in the lifetime of this plant.

And there's a camp that believes that we take a very deterministic approach to that final fission product barrier and call that kind of covering for our residual risk. You're limiting that. You are the first. No one has done that. It's a huge risk.

And to date, we've not seen a functional containment topical, although we are covering it a little bit here. We've had the conversation whatever, a few months ago, a number of months ago. And Eric Williams did a good job of articulating position, but that doesn't necessarily change our minds. This is a substantial change.

And in the spirit of advisory, we would advise that you be more transparent and maybe go as far as to create a Functional Containment Topical Report. You hit this issue hard, because it's going to continue to come up.

So, it's not really a question, but advice.

MR. SINODIS: Thank you. Appreciate the

comment.

CHAIR ROBERTS: And not to beat this too much, I just wanted to read from the letter we wrote back in January.

(Laughter.)

So, this is on the Principal Design Criteria. We ended this recommendation in conclusion No. 2.

It says, "Therefore, the functional containment approach is expected to maintain significant defense-in-depth capability comparable to prior SFRs."

So, I guess we'll give you a chance here in the open session. Is that stated wrong? Should we correct that statement, so that you would agree with it?

MR. SINODIS: Do you mind actually reading it one more time?

CHAIR ROBERTS: Yes. "Therefore, the functional containment approach is expected to maintain significant defense-in-depth capability comparable to prior SFRs."

MR. SINODIS: I don't believe -- I think, as we've talked about and as was discussed in the PDC meetings as well --

(Audio interruption.)

CHAIR ROBERTS: Somebody has a live microphone. Check to see if you have a live microphone.

Go ahead. It looks like we've cleared the live mics.

MR. FORREST: So, thank you.

What I was going to say -- again, this is Chris Forrest with TerraPower -- I think the defense, like when we compare to historical SFRs, I think we need to acknowledge that defense-in-depth may look different. Like we have different design features.

And another important piece related to that is the use and the implementation of mechanistic source term. So, when we talk about containment as being the final barrier, many times and historically, that's in relation to using a non-mechanistic source term to start with.

And so, when we are approaching our source term analysis using a mechanistic source term and we're developing event-specific source terms, we also develop our functional containment barriers based on the needed performance against those event-specific source terms and the progression of those events.

MEMBER PETTI: So, I think what you think

-- it's not the same defense-in-depth implementation, but, in aggregate, it may have the same level. It's how you get there is different?

MR. FORREST: Correct.

CHAIR ROBERTS: All right. We had to use the word "comparable" in our letter, not the same.

That's probably as far as we're going to get in the open session. I'm sure we'll visit it again in the closed session.

MR. ANZALONE: If I can, I'd like to chime-in a little bit and just say that, you know, the functional -- sorry, this is Reed Anzalone of the staff.

The functional containment barriers on the performance are definitely an area that we're reviewing in a lot of detail in the Construction Permit Application. So, you know, we're going to get into that over the coming months with you.

CHAIR ROBERTS: Okay. And thanks, Reed. Okay.

MR. SINODIS: Next slide.

So, the element two of EMDAP, following that is a guideline or framework. It's developing an assessment base for the source term EM. So, we evaluate existing tests, benchmarks, simple test problems, and legacy plant transient data.

As a submission, we had a PIRT for selected scenarios and a ranking of the phenomena processes have been completed as part of that effort.

Also, since the Topical Report has been submitted, just as a reminder, even though it was submitted whenever it was, work has been ongoing over the past 14-15 months since its submittal. So, in that time, some scaling analysis has been performed, qualification efforts, and our experimental work related to uncertainty measurement errors and experimental distortions have been underway.

And I think an important thing to note here is, wherever this is experimental data lacking or uncertainties, we generally apply conservative approaches in this regard. So, those conservative approaches are outlined in the Topical Report.

Next slide.

So, part of element three is developing the EM Development Plan. So, the source term EM consists of a group of software codes, and that group of software takes output from upstream software codes and EMs -- for example, the Fuel Failure with Release Evaluation Model -- that are all used as input to the source term EM.

And then, output from the source term EM, as we talked about in the RADCON session, is used as input to the Radiological Consequence Evaluation Model.

Also, as part of the Development Plan, we described life cycle and verification and validation plans for the source term software codes, and any local capability gaps have been identified at the plants to fill the gaps, as noted in the Topical Report.

Next slide, please.

Also, it describes the structure of the evaluation model on a macro level and a micro level. Sort of on the micro level, in the Topical Report, we describe the structure of the individual software codes or calculational devices and talk about the six ingredients that are mentioned in Reg Guide 1.203, such as the systems and components, constituent phases, field equations, closure relations, numerics, and any additional software code features that may be utilized.

And then, more on the macro level, with the structure of the EM, we describe how it defines and develops interfaces with the upstream and downstream evaluation models.

And then, in regard to closure models, m models are incorporated in the EM for pool scrubbing and aerosol natural deposition, which are the two primary mitigating phenomenon that are considered in the source term EM.

MEMBER PETTI: So, in terms of the scrubbing and the sodium, are you going to get into any details in the closed session?

MR. SINODIS: Yes, we can. Yes.

MEMBER PETTI: I'll put it in the open session. But I think there's some physics missing. Let me see if I can explain this succinctly.

The experiments that were done in Wisconsin, the accident, at least as I envision it, when fuel fails, and you spew the bonded sodium and any fission products into the sodium coolant, that's very hot sodium vapor going into relatively cold, shall we say, coolant.

When you do that, the models, as I understand it, reading the Argonne reports, you condense and you get very significant decontamination factors in the sodium. I don't believe that you can condense that much hot sodium. You will form the aerosols. Simply, at those temperatures, you get a lot of radiation heat transfer from the vapor coming out of the fuel rod to -- well, I think of it as a bubble -- to the surface of the pump.

There is no parallel mass transfer to radiation heat transfer. So, as you know from the textbooks, right, there's a heat-transfer-to-mass-transfer correlation at regular conditions. Under these high temperatures, the temperature will drop because of thermal radiation, sigma T to the 4th. So, the vapor pressure will plummet, right, because it's exponential to temperature. But the partial pressure will just go like an ideal gas. That ratio, the saturation ratio, will increase. That's a very non-equilibrium condition and you will form aerosols. That's how you form aerosols. It's nucleation classes.

Assuming it all condenses is not conservative. So, I'm not arguing that you put those physics in your codes. It's incredibly complicated. I did my PhD thesis on this. So, that's why I know all this.

What you need to do, though, is sensitivity studies where you assume it's all aerosol. Because you've got enough barriers, it may not make any difference at the end, right? It's just a case where some of the physics here, particularly in the higher-temperature accidents, you have to do some sensitivity to kind of bound what you think is going on.

And you form very fine aerosols. So, you know, I'd start it at .01 microns and let the code do the aerosol physics to see if the aerosol physics will compensate for the vapor condensation assumption.

So, there's just something in the detail there. I wanted the staff to be aware of it as well. You only see it in, like, MHD, and in severe accidents. This is why I know this stuff because I did it severe accidents.

That's all. I wouldn't put in the code for sure. It's incredibly -- it will make your numerics really bad.

MR. SINODIS: I see Sam Miller has his hand up. So, I'll let him chime-in.

Sam?

MR. MILLER: Yes, I just wanted to comment on the state of the sodium bond within the fuel pin.

So, the sodium bond, due to fuel swelling, gets pushed into the upper plenum region of the fuel pin. And so, that's like the mixing temperature above the fuel. So, it's very similar to the coolant temperature and is mostly liquid inside the fuel pin.

MEMBER PETTI: So, you think that, when the rod fails, that vapor is pretty close to the coolant temperature?

MR. MILLER: Yes. So, it's liquid and there is gas above it. And so, then, the fuel failure occurring in the fuel region, that gas pressure, of course, is the liquid sodium bond out into the coolant.

MEMBER PETTI: Right. Right.

MR. MILLER: And there are fission products in that sodium --

MEMBER PETTI: Right, yes.

MR. MILLER: -- to some degree, but it's a liquid base.

MEMBER PETTI: Oh, I guess I was confused then. Because the Argonne paper had release fractions from the fuel and it had 1100-degree and 1300-degree columns, which I think were the protected and unprotected events. So, I guess I kind of assumed that those temperatures were tied to what was being ejected from the rod. That's not the case, is what you're saying?

MR. CHANG: This is Jong Chang.

Dr. Petti, you are referring to, like, the inner side of, like, that generic SFR --

MEMBER PETTI: Yes.

MR. CHANG: -- system study you mentioned?

Yes. Those cases, that's a problem like a beyond-design-basis accident cases, which drives at a higher fuel temperature and, also, higher cladding temperature. So, that's why that bonding to sodium has the same -- we expect or we saw, like, that's phase during, like, a normal operation for our design-basis accident conditions.

However, it's like low-frequency domains. So, it will be elevated temperature. So, typically, like, I believe Argonne National Lab cases, like, go even beyond that, pushing the envelope to, like, an unprotected event with, like, say, degraded loss-of-heat-sink type of cases. So, then, that elevated temperature puts into, like, a vapor, a phase of like a sodium. So, then, they would have, like, a more pushing-out-like event.

MEMBER PETTI: Okay. I understand. I figured it was a very low-frequency event. I just wanted to make sure in my mind I understand the physics, though.

In those types of events, is the sodium bond at those higher temperatures as well? I agree with you that maybe in many of the other design-basis events this is not an issue that I raised. It is really in these more higher-temperature. What is the sodium bond temperature predicted in an unprotected or protected loss of flow? Is it as high as the temperatures in the Argonne report?

Because they got fission product release at 1100 degrees and at 1300 degrees. I looked at that table and I said, well, gee, the fuel was not a very strong barrier at those temperatures. So, I assumed the sodium was very much similar in temperature there. Is that true?

MR. CHANG: We need to go back to, like, actual event cases and do a bit better as to that question.

MEMBER PETTI: Yes. So, I mean, yes, I understand many events, this won't be a case. But if you actually get to those temperatures of the sodium bond, it's as high as those temperatures in the Argonne report then. Okay.

MR. FORREST: I will acknowledge that the uncertainty in those areas is high, and we understand that. And that's something that we're trying to characterize.

MEMBER PETTI: Sure. Just how it comes out and it mixes with this, I mean, that's really complicated stuff, yes.

MR. SINODIS: Thank you. Excellent.

So, also, the Topical Report describes various modeling strategies that are being employed, such as sodium chemical reaction modeling; determining dose-significant radionuclides for input into the calculational devices; describing functional containment modeling, like determining compartment conditions; determining barrier leakage rates, and then, the radionuclide transport and mitigation phenomenon. So, general strategies are described in the Topical Report.

MEMBER PETTI: In terms of the chemical reaction modeling, yes, I think MELCOR was mentioned in the report as being a tool that can handle this. Is the model going to be extended to reaction of the aerosols themselves with the oxidant, I guess, you know, air?

MR. CHANG: Dr. Petti, this is Jong Chang again.

Yes, I think the Sandia National Laboratory, and also sponsored by the U.S. Nuclear Regulatory Commission, I think that there were several workshops on sodium chemical reaction capability with MELCOR was, I think, demonstrated.

So, I believe, like, currently, a new MELCOR Version 2.2-something, I believe. So, then, that has, like, a chemical oxidation model, so sodium can react with, like, oxygen.

MEMBER PETTI: I can imagine, like, a pool, but are they going to react the aerosol because of the vapor pressure of sodium changing its chemical form, fission products changing the chemical form? It could change the shape factor of aerosols, you know, whether they're flocculant. In water, they're very spherical. You don't have water here. Is MELCOR going to do that sort of stuff? Do you know?

MR. CHANG: That's beyond -- we can't answer that question.

MEMBER PETTI: Okay. Again, this is just one of those areas of uncertainty.

MR. SINODIS: I will say, generally, in those uncertain areas where there is high level of uncertainty, we generally treat those -- make conservative assumptions.

MEMBER PETTI: Or, you know, do sensitivity studies.

MR. SINODIS: Correct. Yes. Yes.

Next slide, please.

And then, the last phase of the EMDAP is doing the adequacy assessment. And this is just kind of outlined in the Topical Report and this is some of the areas where there's still work ongoing on it.

So, determine the capability of the equations and solutions to represent processes encountered; simulating system components. Code verifications have been conducted for the software codes used, and validations, some have been conducted; some are ongoing. Strategy for gaps. The V&Vs have been outlined, and then, your model prediction biases and uncertainties will continue to be developed as necessary, as the process works through.

We do talk about in the Topical Report comparing the Natrium methodology to Reg Guide 1.183, Regulatory Positions 2.1 through 2.5, about using an alternative source term. And those sections refer to Rev. 0 of that Reg Guide. And those positions are listed in Rev. 1 and proposed in Draft Rev. 2. They're just under different numbering.

In this section of the Topical Report, we also identify potential source lists and releases, the release types and end points. Performing the code identification evaluation for the release modeling and code verifications against the underlying model fidelity and accuracy. And once again, these are various works that are still ongoing.

MEMBER PETTI: So, just another question. You mentioned Reg Guide 1.183. One of the things in reading the report that jumped into my mind was the SECY-93-087 about the adequacy of the -- the database has to be good enough to enable a mechanistic source term, basically -- my words; they used more eloquent words -- for the staff to be able to come to their finding.

The Topical Report is silent on do you need that. The staff is silent in the NRC. It would seem to me that, if you're going to issue another revision, that you spend a little bit of time talking about the underlying databases and why you think that this is -- that the database as it exists is sufficient enough to do a good calculation and to make a regulatory finding.

Because, you know, it's out of -- it's new, right, taking this in sodium fast reactors. I would argue the fuel database, Argonne did a yeoman's job. It's Swiss cheese. There's a lot of data gaps. And hopefully, the other boundaries, the other barriers are going to make up for that.

Honestly, I was anticipating that there would be some testing of fuel done at different temperatures and burnups. That hasn't really happened. The database is largely coming from the refining work that was done in the old days. So, it puts you guys in a very difficult position, I think.

But I think some sort of statement about why you think, in total, you know, you can do this, and then, how your conservative assumptions, kind of how all that maps together in a succinct statement would probably be helpful for anybody, I think.

CHAIR ROBERTS: Just for the record, I think you're referring to SECY-95-092, just to remember?

MEMBER PETTI: Yes, 092.

CHAIR ROBERTS: Yes. It says, "Sufficient data should exist on the reactor and fuel performance through the research, development, and testing programs to provide adequate confidence in the mechanistic approach." The paragraph that you're referring to?

MEMBER PETTI: Yes, yes.

MEMBER MARTIN: I'll jump in here.

It's a pretty high-level presentation. I know you have another slide here. But, really, what I kind of expected to appear in the open session is, you know, the source terms ultimately feed various calculations related to radiological things.

And, you know, light water reactors, you might have six, seven, eight different buckets that ultimately feed the different calculations that would have appeared in Chapter 15.

You haven't presented that. Maybe we'll explore that in the closed session. But there really is nothing proprietary about, you know, what analyses you will do and what feeds those sort of things.

I realize you have a couple of sample problems in the Topical Report, but, really, in the spirit of transparency and that sort of thing, we really should be coming out here in the open.

I think we do have a member of the public on the line, at least one, if not more. And he probably has spotted this as well.

But these sort of things matter and you're flying maybe at 50,000 feet, and you could probably have gone down to at least, you know, 5 or 10 thousand feet on some of the details. But just advice for next time.

MR. SINODIS: Yes. So here, we're talking about just interfacing with the downstream EM. And this is covered a little bit in the radiological consequences presentation.

So, the output of the source term EM are time-dependent matrices of the radionuclide inventory that gets released to the environment. And the format and periodicity of the output is event-specific and software-dependent. So, you know, as mentioned earlier, the source term EM is supplied to all sorts of different events, and depending on the event and the software used, will dictate that format and periodicity of that output. And then, the data is transferred between the EMs via control of electronic files.

And as Dr. Martin mentioned, the Topical Report contains two sample calculations demonstrating the application of the Source Term Evaluation Model.

MEMBER PETTI: Let me ask a question about uncertainty, approach and propagation. I think this is the first time at least that I've seen multiple codes. How are you going to propagate uncertainty from one code to the next, to the next? Because, you know, it's really what's at the end that you care about.

That's really different than, you know, some of the Monte Carlo sort of stuff that's seen, where you take a code and you get 10 different parameters, and you're going to vary them. And you've got one figure of merit.

It could be extremely complex, it would seem to me, to kind of approach this because there's more than one computer code involved. Have you guys given that any thought?

This is why I worry about some of them going to a freeze. So, I'm glad you're not using them in the strictest sense because I think you could get into a very deep hole.

MR. SINODIS: Thank you. I will, yes, some of the codes -- and we'll get into this a little more in the closed session -- are used for, say, DBA analysis as one code, and then, the other code is used for other LBE analyses, you know, that kind of thing. So, those codes do not necessarily feed each other all of the time, depending on the event. And then, some of the other codes are used more for supporting analyses or to determine things like the functional containment, barrier traits, that sort of thing.

MEMBER PETTI: I do want to say, I mean, I thought the report was comprehensive in terms of the different source term pathways. Because we always focus on the reactor because that's what we like to do, but all the other subsystems with a lot of radioactivity and the fuel-handling stuff, given it's an opaque coolant, moving fuel is not the simplest thing in the world. I thought that that was well-covered and appeared to bracket everything that you would want to think about.

MR. SINODIS: Thank you.

I believe that's the last slide in the presentation. So, I'll entertain any other questions at this point.

CHAIR ROBERTS: Maybe one of you could talk briefly about OQE, which in this presentation means "other quantified events." We had some discussion in the EPZ Topical Report discussion about cutoffs for events that are determined to be cliff-edge effects or defense-in-depth. Is that the OQEs or are there other reasons to include events that are not treated as LBEs?

MR. FORREST: I can speak to that. I've got a few points related to that.

This is Chris Forrest from TerraPower.

And it also relates to Dr. Martin's comment just about the number of different kinds of LBEs that we're analyzing, and in the spirit of more transparency in the open session, I'll try to address kind of both of those things.

And before going into it, I'll also

upfront say that I am not a PRA analyst. So, I'm not going to be able to speak specifically to the frequency of the events, but I can speak a little bit about how mechanistic source term and PRA is interfacing together, as we go through the LMP process.

So, to answer the question about OQEs, OQEs are other quantified events and they are categorized below our 5E-minus-7 cutoff, which is the lowest frequency of our BDBE region.

And so, those are still considered -- they are quantified, even though there are other quantified events, they are quantified in the PRA and, as such, they also need source term and consequence values assigned to them.

The sort of high-level steps that we take, as we go through NEI 18-04 in this iterative process, is that PRA develops event sequence quantification and assigns release category end states to those events. Those are the single initiating event sequences that, then, end in release.

And so, we have sort of a first-step mechanistic source term analysis that would develop source terms and consequences for each of those release category end states. Those get assigned in the PRA, and the rest of the PRA quantification is performed, such that we end up with an event selection and our official event list. And the LBE event list is a smaller set than the large quantity of event sequences that are analyzed in the PRA.

So, those initial source terms that we do to support the event sequence quantification are all non-DBA. We would use our best-estimate approach with uncertainty or choose to take conservative inputs and assumptions in those cases as well, if it's warranted, or the uncertainty information is lacking.

So, then, the PRA goes through and quantifies it and we come up with the LBE list, and that LBE list is going to describe our AOOs, our DBEs, our BDBEs, and also, the selection of DBAs from the DBEs.

And what's not presented in that LBE list is the other quantified events, but they are in the PRA, you know, upstream in that event sequence quantification. They are still assigned consequences up in that upstream work. And they're retained by PRA to look at for those cliff-edge effects and consideration, to some extent, in the EPZ process as well.

And to Dr. Martin's sort of question about types of events, you know, yes, of course, we're principally concerned with in-vessel events and what's going on with the core. But, out of that event sequence selection that PRA does and that process, we identify events all over the plant. So, we've got our in-vessel events. We've got our fuel-handling events that may happen, fuel-handling in-vessel and, also, fuel-handling ex-vessel, all the way to storage in the spent fuel pool.

In addition, we quantify releases from auxiliary systems, so our activated gas and activated sodium systems as well. So, part of the mechanistic source term analysis for our LBEs encompasses all of those possible events.

MEMBER PETTI: So, are there actual event trees for those auxiliary systems or is it just --

MR. FORREST: Yes, there are.

MEMBER PETTI: So they're doing it from a risk perspective?

MR. FORREST: Yes.

MEMBER PETTI: That would be interesting.

I had another question, which was if an OQE who was processed, people challenged the frequency -- again, you're not the PRA guys -- so that it -- maybe it really should be a beyond-design-basis event, move it up a notch -- does it really change anything you guys are doing from a source term? I mean, you've got calculated the source terms, but you tell me, okay, if you move it up, as long as it doesn't get into design-basis space, does it really matter in a practical sense?

MR. FORREST: Right, you're kind of getting at the iteration that we go through with PRA, and also design as well. So if we have an OQE that we've assigned a consequence to, in many cases the consequences that we produce aren't necessarily strictly tied -- like in that first iteration when we produce consequences for release category end states, that's not necessarily tied to a frequency yet. It's just a here's a scenario; here's the barriers that -- you know, this is intact; this is failed; what's your consequence? So we're characterizing like a scenario without -- agnostic to frequency.

So if that particular consequence or event -- like if there's reason to move that up from OQE to BDBE, then we would be considering our -- in the consequence space our margin to the F-C target, our potential for going into our risk-significant region, which means we're getting close to that curve. And we might start identifying SSCs that may need to change their classification or have some special treatment applied to ensure that we're not approaching the curve or crossing it.

MEMBER PETTI: But if it was -- it's a little bit higher. Because it's a lower frequency, as long as it doesn't challenge the F-C curve, unless you've got some internal margin that you're trying to shoot for on the design, I can see that iteration when you forge because that's what LMP does --

MR. FORREST: Sure.

MEMBER PETTI: -- right? It tells you how to do that. Okay.

CHAIR ROBERTS: Yes, I understand the frequency aspect to it, but there are some scenarios that you include just because they've been historically included like specifically the unprotected transient overpower, the unprotected loss of flow. I assume in frequency space they're very low. And so you would not have them on an F-C curve per se, but they've also been historically assessed to show margin for sodium fast reactors to certain events. And presumably I guess I'm asking are those included in the OQE list regardless of frequency?

MR. FORREST: Those events are quantified in our PRA.

CHAIR ROBERTS: And so if they were to screen out you would not evaluate them for consequence?

MR. FORREST: Screen out in what --

CHAIR ROBERTS: What frequency?

MR. FORREST: We still assign a consequence.

CHAIR ROBERTS: Okay. So yes, that's what I'm asking. So you would evaluate the consequence of these events that are potentially well below the frequency cutoff, but I would assume you're calculating a number well below 5x10 to -7 for an unprotected transient overpower, for example.

MR. FORREST: Yes.

CHAIR ROBERTS: And yet there's still this history that that's an analyzed event for SFRs because, you know, again, may be historic, but the potential concerns to where it leads.

MR. FORREST: Sure.

CHAIR ROBERTS: So you would I guess check that box and verify that if it happened it would lead to those historically, you know, historic concerns like hypothetical core destruction and that kind of thing?

MR. FORREST: Well, we do quantify the

unprotected events.

CHAIR ROBERTS: Okay. And that would be an OQE?

MR. FORREST: I can't say off the top of my head where it's landing in frequency, but it's quantified so it falls within our LBE categories or it is an OQE. We assign it consequence.

MEMBER PETTI: But it just seemed to me just because of this historical stuff, independent of the methodology that's used, there should be a paragraph somewhere with it, I mean particularly if the answer is it still would meet the F-C curve just because of all the historical stuff that's there for that SFR to be able to make a good statement, a strong statement I think from a public perception standpoint.

CHAIR ROBERTS: Right, and then that's where I was heading, too. If you get beyond that corner of the F-C curve and the LMP -- and the curve was -- like it's horizontal if I remember the orientation of the axes right -- which sends a message of it doesn't matter what the consequence is. I think what Dave suggested, or I'm suggesting is for these historic events maybe you do want to kind of pin them at that corner and say even if the frequency is much, much less, you still want to show that the consequence is bounded by the corner of the F-C curve. Just something to think about.

MR. FORREST: Yes, thank you.

CHAIR ROBERTS: Thank you.

Any other questions for the applicant in this open session?

(No audible response.)

CHAIR ROBERTS: Not seeing or hearing any, let's go ahead and transition to the staff. So again, we'll have about a two-minute break while we change out the presenters and the -- whoever's presenting the presentation on the team and we'll restart in a couple minutes.

(Pause.)

CHAIR ROBERTS: Looks like we're ready.

Okay. Stephanie kicks us off. We're ready.

MS. DEVLIN-GILL: All right. Good morning, everyone. My name is Stephanie Devlin-Gill. I'm a senior licensing project manager on the Natrium project. We are here today to discuss the NRC staff's review of the Radiological Source Term Methodology Report. It's a topical report.

The agenda is similar to what we followed for the last couple of topical reports, right, where we'll review the staff that are on the project, review the chronology of the review. The technical staff will give a topical report overview. The relationship between the -- this topical report and other TerraPower topical reports, regulatory requirements, the NRC staff's review approach, and limitations and conditions, and conclusions.

Up front with me today are -- you saw them earlier -- Michelle Hart and Zach Gran. In the well also on this review is Reed Anzalone. I'll also acknowledge the leadership of another senior project manager, Mallecia Sutton on this topical report, as well as others. She's the lead project manager on the Natrium project. And I want to thank Kent Howard as well for his leadership from the ACRS staff.

So the review chronology for this topical report: slightly different than the other topical reports you've seen over the last couple of days. During the acceptance review the NRC staff requested that TerraPower supplement its topical report. So we received an early revision to the topical report so that once we receive that supplement we could -- the NRC staff began its full review of the topical report.

Similar to the other topical reports we conducted a regulatory audit from May to August of

2024. And after that time TerraPower supplied another revision to the topical report. So similar to as Michelle mentioned on the last topical report, there was a number change. So just something to note, right? The number of the topical report changed. So the revision, Revision 0 -- it became Revision 0 after the number change, right? And this topical report is linked similar as we've discussed before to the construction permit application.

I will turn this presentation over to Zach Gran.

MR. GRAN: Thanks, Stephanie.

Again, my name is Zach Gran and I am a reactor scientist and technical reviewer in NRR. I'll be presenting the next few slides including this topical report overview.

This topical report is intended for use in the Natrium license applications under Part 50 using the Licensing Modernization Project approach. This methodology described in this report is to determent the event-specific source terms for use in subsequent dose analysis. No specific source term calculations are being provided or approved of in this topical report. And this topical report provides the evaluation model used to determine the mechanistic source terms for the proposed Natrium design.

Next slide, please? This slide discusses the relationship to other TerraPower topical reports similar to what we had for the consequence. This topical report is an input into the Radiological Release Consequences Methodology Topical Report. This method determines the source term inputs for determining the radiological dose consequence. This source term methodology does not determine the licensing basis events, the design-basis accidents, or other quantified event scenarios that result in a radiological release.

Next slide, please? This slide is a summary of the regulatory requirement for consequence analysis. The source term methodology is needed to determine the source term that are input into the dose analysis to show compliance with these regulations.

Next slide, please? So now we start with the NRC staff's review approach to this methodology. Starting with this slide and the next two slides I'll explain the review approach taken to do our review. The NRC staff considered a number of documents in our evaluation.

Starting with Reg Guide 1.183, this Reg Guide is written for light water reactor design-basis accident MHA source terms and consequence analysis using an alternative source term. In Reg Guide 1.183, Regulatory Position 2, it states the attributes of an acceptable accident source term. And so it states that the source terms have aspects that are generally technology-neutral including that the accident source term has a defensible technical basis supported by sufficient experimental and empirical data and is verified and validated, and is documented in scrutable form that facilitates public review and discourse.

As discussed in SECY-93-092 a mechanistic source term is the result of an analysis of fission product releases based on the amount of cladding damage, fuel damage, and core damage resulting from specific accident sequences being evaluated and is developed by using best estimate phenomenological models of the transport of the fission products from the fuel through the reactor coolant system, through all holdup and barriers taking into account mitigation features and transfer into the environs.

And then SECY-18-0096 describes the functional containment concept as a barrier or set of barriers taken together that effectively limits the physical transport of radioactive material to environment.

Next slide, please? Continuing on with review documents, because the LMP methodology uses a facility-specific PRA, to aid the review of the source term methodology the NRC staff also used the guidance in Reg Guide 1.247, the non-LWR PRA standard as endorsed for trial use.

Specifically the NRC staff used the discussion of the MST analysis PRA element and supporting requirements as a guide to direct our review. We also note that we did not evaluate the acceptability of the Natrium PRA in this evaluation.

Next slide, please? The last method considered in the NRC staff's evaluation of the source term methodology included the guidance contained in Reg Guide 1.203, Transient and Accident Analysis Methods. This was the first time the NRC staff reviewed the MST methodology in this context. The NRC staff review of the topical report methodology considered the guidance of EMDAP with a focus on the modeling of radiological -- or radionuclide transport and retention phenomena to provide mechanistic source terms for use in licensing applications. On this Reg Guide the NRC staff highlights that this guidance was also not used to determine the acceptability of the source term methodology.

Next slide, please?

MEMBER PETTI: So let me just ask you on that then. What we heard from them, from the applicant was that sort of the intent instead of the letter of the law. Is that the way you looked at it, too?

MR. GRAN: Like a means to describe the process or how they're going to kind of relay information to us so that we can understand their approach taken.

MEMBER PETTI: Yes, because there's a lot of stuff there that really doesn't make sense from a source term perspective. Thank you.

MR. GRAN: Right. Now the last slide I'll be presenting is just kind of an overview of the EMDAP process. Just to highlight, this slide highlights that the EMDAP process consists of four main elements followed by an adequacy decision. At the end each element being broken into its concurrent steps.

Just to reiterate, we used this as kind of the guide of how they presented information to kind of take it in and understand the codes being described and how -- what kind of information is provided. Like the information on the PIRT, et cetera, was all used to kind of understand what they're trying to do.

Now this wraps up my slides and I pass it off to Michelle.

MEMBER PETTI: Just a question. I mean, you guys have been up at this table with us on source term before. This struck me as very much a process topical. That's not what we've seen in other applicants. To me, all the interesting stuff, not being a process person, were in the references. The Argon reports which were quite detailed -- and although they may not be the real numbers that the applicant will use, they at least helped me understand a lot more how to take the process and make it real, I guess if you will, from the abstract to something more concrete. This is not what we usually see for source term topical reports. I mean, each applicant can do it differently, but is that fair to say?

MS. HART: This is Michelle Hart. Yes, of course. I had a similar response when I first read it, and it took us a bit of thinking through how we were going to do this review because, yes, it did strike me more as a process-oriented thing. This is the first time I've really been engaged more as like a safety analysis review. And the use of the EMDAP was new to us as well.

Along with you, yes, I found the reference reports to be very instructive. And they are referring to them in the methodologies being used by the applicant for the analysts, to help them actually run the methodology.

But, yes, it's very different now. Of course you say I've been in front of you a lot of times with source terms. It's been like once. So there's not really a --

MEMBER PETTI: Hold it. What point (audio interference) --

MS. HART: Mechanistic source term. Well, put --

MEMBER PETTI: Okay.

MS. HART: -- Reg Guide 1.183 to the side. Light water reactor source terms is not an event-specific mechanistic source term in the context of a PRA or an LMP. And so this is really the first time we're seeing sets of types of topical reports that describe these methodologies. And they're describing methodologies as opposed to describing the actual source terms and the output, which is what we have seen more frequently in the discussion of Reg Guide 1.183.

MEMBER PETTI: Well, I'm glad you had the same reaction. So just to foreshadow, our letter is going to be less focused on process and more processed on this issue that's in the SECY about adequacy and talk through each of the data sets because we maybe thought that would be more useful to you guys. You guys are really good at process stuff. We're awful at that stuff. We're much better at --

MS. HART: We can complement each other --

MEMBER PETTI: Correct.

MS. HART: -- on this particular aspect, yes.

MEMBER PETTI: Yes.

MS. HART: I understand.

Okay. So next slide, please? Again, my name is Michelle Hart. I'm a senior reactor engineer in NRR and DANU. I'll talk now about the NRC staff's review, and the first topical we'll talk about is the use of the EMDAP as a framework for evaluating the determination of MST the way that they've described it -- MST being mechanistic source terms -- the way they've described in their topical report.

We did orient our safety evaluation. It took us a little bit of time to figure out how to actually write our safety evaluation report. We did orient it around the EMDAP elements, although the really interesting meaty stuff is in the closure models, as you're trying to say the stuff that goes more to the specifics of determining a mechanistic source term. So we'll have a little bit extra discussion there and we'll kind of switch to using the PRA elements and the Reg Guide 1.183-kind of discussion of source terms when we look at those closure models and the specifics of the codes.

Next slide, please? So TerraPower did state that they considered the EMDAP guidance as industry best practice as they had talked about earlier as well, but they did not intend for the source term evaluation model to be verbatim conformance with Reg Guide 1.203. So we did not review it in the context of trying to find verbatim conformance.

We did determine that the use of the EMDAP guidance is appropriate for describing the framework of source term methodology because it allows us to understand, as Zach had said, the use of the analytical tools and the methodology assessment, and how the upstream and downstream processes relate to the source term evaluation model.

Next slide, please? So the first element is the source term EM capability that we're going to talk about now. The source term evaluation model outputs are mechanistic source terms intended for use in the LMP-based license applications or other best-estimate plus uncertainty analyses. And we did impose a limitation and condition related to this.

As TerraPower had talked about earlier today in their PIRT, they had used some figures of merit. And we determined those to be consistent with the dose criteria described in the regulation and for uses within the LMP and would help you determine the phenomena related to mechanistic source terms to resolved in those kind of figures of merit.

The design information. The topical report describes the preliminary and design information that was used at the time to develop the evaluation model, and the topical report had written three limitations on the use of the topical report related to the design information.

Next slide, please? They did perform PIRTs. They used the PIRT for identification of phenomena and barriers important to the development of mechanistic source term for the proposed Natrium reactor design. The dose-based figures of merit from EMDAP Step 2 were used in the ranking and we determined that the PIRT is acceptable for the methodology scope because using a PIRT is consistent with Reg Guide 1.203. And source term phenomena and ranking are appropriate for the scenarios considered in the evaluation model because they are consistent with the proposed Natrium design and past sodium fast reactor operating experience.

Next slide, please? To go to the assessment base for the source term evaluation model, it's used to validate the calculational devices or codes and may consist of a combination of legacy experiments and new experiments in a general sense. We determined that the methodology provided in the topical report section is consistent with guidance for EMDAP Element 2. The topical report described the process for determining the phenomena of interest and describes the process of obtaining existing experimental data or using conservative approaches to address concerns with uncertainty phenomena relevant to MST.

They did describe that there is -- ongoing work is planned to be completed prior to the submittal of an operating license application and relevant information will be included in a future licensing submittal. And we did impose a limitation and condition to acknowledge that they say that there is ongoing work. They did not describe the specific ongoing work. I think they're still planning as part of the iterative process of the EMDAP. They're still evaluating that.

Next slide, please? As far as the source term evaluation model structure the topical report discusses the use of RADTRAD and some other computer codes. We did audit documentation of each computer code cited in the evaluation model and we determined that the computer codes address mechanistic source term phenomena and are fit to the purpose.

We verified inputs into this source term evaluation model and how the computer codes account for the phenomena identified in Element 1. And we -- our review determined that the process delineated in the topical report is acceptable because it provides sufficient information to understand the computer codes and computer code capabilities consistent with the guidance in Reg Guide 1.203.

Next slide, please? Now we go to the source term characterization. We determined that the information contained in the topical report and the reference documents justifies the method of identifying risk-significant radionuclides because the referenced national laboratory reports are relevant to sodium fast reactor designs.

We also determined that the models in the computer code and the topical report discussion of use of the codes, including parameter selection, reflect the physical and chemical forms of released radionuclides from a sodium fast reactor design in general.

And we determined that the topical report is consistent with the descriptions of source term characterization in the non-light water reactor PRA standard as endorsed in Reg Guide 1.247 for mechanistic source term analysis for the use in risk-informed activities, which LMP is considered to be a risk-informed activity, and the general aspects of source term characterization as described in Reg Guide 1.183.

Next slide, please? To go to the source term closure models, the source term evaluation modeled radionuclide transport and retention phenomena, either by models built into computer codes or by user-defined assumptions to those codes. The topical report includes an overview of the closure relationship and phenomenological models for each of the computer codes used in the source term evaluation model. And the closure models discussed in the topical report in more detail are pool scrubbing, aerosol radionuclide natural deposition, functional containment modeling strategy, and radionuclide transport.

Next slide, please? So there's two different kinds of pool scrubbing. There's the sodium pool scrubbing for events in the reactor and then there's spent fuel pool water scrubbing for the spent fuel in the spent fuel pool.

For the sodium pool scrubbing they had written a limitation that we carried forward as Limitation and Condition 4 that we applied to the modeling of radionuclide removal through aerosol scrubbing in the subcooled sodium pool.

The spent fuel pool water scrubbing, they used a model that was based off of the assumptions in Reg Guide 1.183 for light water reactor spent fuel pools and they applied that as being conservative for the spent fuel pool water scrubbing. It's reasonable and is subject to evaluation in subsequent analyses which implements the topical report, which they do describe that they will justify that.

Next slide, please? So for aerosol radionuclide natural deposition the topical report states that aerosol natural deposition is credited in the cover gas region for design-basis accidents. In that case they're using the RADTRAD code as -- and the Henry's correlation in that code, which is an aerosol gravitational settling model implemented into RADTRAD, and they're using that.

The Henry's correlation is based on aerosol removal experiments which use sodium oxide aerosols. And we determined that they are similar in size distribution to the potential aerosol releases from a sodium pool and as could be anticipated for the Natrium design-basis accidents. And we also determined the RADTRAD implementation of Henry's correlation is conservative because it only accounts for radioactive aerosols in determining the aerosol density. It doesn't account for the non-radioactive aerosols. So it would result in less gravitational settling.

And therefore, we find the modeling of aerosol transport retention in the functional containment, specifically the cover gas region, to be acceptable.

Next slide, please? And then TerraPower had discussed their functional containment modeling strategy. We're repeating here on this slide what they said the containment modeling strategy includes. I don't think we necessarily need to go into any more detail on that. We had a discussion about that earlier.

Next slide, please? We determined that the topical report methodology strategy for modeling functional containment is acceptable because it provides a structured evaluation of the barriers to radionuclide release for each event and it assesses the sensitivity of final dose results to the functional containment modeling assumptions.

We determined that the selected code that provides event-specific thermal-hydraulic conditions within the functional containment is appropriate because it is consistent with this code purpose and that the handling of potential sodium fires is adequate because it uses a code applicable for sodium fires.

Next slide, please? For radionuclide transport we determined that the topical report methodology strategy for modeling of radioactive material transport is acceptable because it provides a structured evaluation of the radionuclide release from the fuel and models transport and retention phenomena within the barriers to radionuclide release for each event.

We determined that the radionuclide

mitigation phenomena listed in the topical report are consistent with the discussion of potential radionuclide transport mechanisms in the non-light water reactor PRA standard mechanistic source term analysis element are endorsed by Reg Guide 1.247.

And we also confirmed that the topical report radionuclide transport retention models are based on first principles, or are empirically derived, are models that are consistent with technology-inclusive phenomenological models used in the NRC-developed version of the RADTRAD code and use conservatively biased user inputs as described in the topical report.

Next slide, please? Let's talk a little bit about the uncertainties in the mechanistic source term and transport phenomena. We determined that the methodology accounts for uncertainties in the modeling of source term phenomena by recommending the use of conservative approaches as justified. And that is also subject to Limitation and Condition 6, which we imposed.

The NRC staff determined that the discussion of uncertainty is consistent with the characteristics and attributes to achieve the objectives of an mechanistic source term as identified in Reg Guide 1.247 and the non-light water reactor PRA standard MST elements.

Next slide, please? As far as the adequacy assessment as we discussed they used this as a -- the EMDAP as a framework for describing their EM. They have not made the -- they have not finished the adequacy assessment at this time. And they do describe some ongoing work that they are doing and future plans. And we did provide a limitation and condition to ensure that the evaluation model is sufficient for the methodology development stage given the relevance of the methodology at the construction permit stage. It's appropriate that it's not complete at this time, or it's acceptable that it's not complete at this time.

Next slide, please?

MEMBER HALNON: Michelle, real quick. This is Greg. If they were following 1.203 language, what would you be calling this portion of the -- your confirmation that the model was adequate?

MS. HART: For the construction permit stage I think it's still appropriate that it's not completely --

MEMBER HALNON: Yes, I agree.

MS. HART: -- that that's all been done at this point. I think the discussion that they've had, the codes that they're using, there's a good base there to give the information, to give the source terms that are appropriate for a preliminary design even to evaluate the siting.

MEMBER HALNON: Okay. So it's certainly headed in the right direction?

MS. HART: Correct. I don't -- our initial assessment is there's not any huge holes subject to whatever additional information we may get from a specialist --

MEMBER HALNON: From (audio interference)?

MS. HART: -- with the ACRS. Yes. Yes, but I think it's -- the universe of information that we have, the types of evaluation models that are already pre-existing out there seem to cover sufficiently for a construction permit.

MEMBER HALNON: Okay. Thanks.

MEMBER PETTI: Let me just ask your opinion. I agree with you on the transport side. I mean, we've studied sodium oxide aerosols.

MS. HART: Yes.

MEMBER PETTI: There are books written on it. I mean, so it's very sound. I'm a little worried about just how well you can characterize natural circulation in compartments. We'll see what that does. I mean, the uncertainly is not in the aerosol physics and the thermal-hydraulics. But what about the fuel? What was your sense when you read the Argon report? I mean, they're releasing actinides at high temperatures. I mean, the numbers -- just comparing to 1.183 in a severe light water reactor the numbers are higher.

MS. HART: They are much higher. I think, yes, there are things that we are not used to dealing with. Do I have to worry about europium now? No, but I guess I'm going to have to in the future, things like that. I think there's a general sense that I get from some of the discussions with TerraPower that their intent is that those events with those very high temperatures are going to be the very low frequency.

And so they can still use those Argon reports to help them model those particular events, but for the majority of the events and the ones that are important, important being in quotes, to help determine the SSC classifications and siting of the reactor are more in the realm of these lower events that are lower temperature events. I'll say that.

MEMBER PETTI: Yes.

MS. HART: But of course that is not part of this methodology. This methodology should be able to handle any of those. So yes, there is still some uncertainty there. And they do talk about how to handle the uncertainty through use of conservation assumptions. I mean, there are certain things where it's obvious what the conservative assumption is. You know, release everything or release what's the higher temperature in the Argon report. Assume that for a lower temperature event if you're unclear about the certainty.

MEMBER PETTI: The other thing that I guess I stumbled on is I understand best-estimate plus uncertainty, but here there could be cases where there's conservative, and then I have to look at uncertainties. And I'm trying to understand how you do that without being so overly conservative. I mean, it kind of kills the whole purpose of best-estimate plus uncertainty if I have to make a conservative assumption.

MS. HART: It's a general concern. I don't expect any of the near-term -- and this is in general. This isn't just TerraPower-focused. I don't expect any of the near-term source terms to really be fully parameter propagation, fully best-estimate plus uncertainty. I would expect some choices that they make for licensing purposes.

What does that really mean for the final results? I don't know that I have personally thought that all the way through. I think it seems reasonable to make these conservative or reasonably determined inputs and assumptions based on sensitivity analyses or whatever to help you determine if you've gotten the landscape of what potentials there are going to be.

MEMBER PETTI: I mean I --

MS. HART: But it's not going to be -- I wouldn't expect any full specific parameterization.

MEMBER PETTI: I also think there will probably be compensation that -- even though the fuel is not necessarily the strongest barrier that the other barriers will probably compensate.

MS. HART: There is an aspect of what is your decision you're making with this information. And so I mean I think as a methodology going in that can be used with particular analyst choices for any of those particular purposes there's going to be some -- as we all practice it, as they practice it, and as we practice reviewing it, some determination about what are the -- what is the right way to talk about this or what is the right level of rigor that you need for these (audio interference).

MEMBER PETTI: It sort of reminds me of the BWR steam line break stuff we were talking about where there was uncertainty over here, but we could take credit where we feel stronger over here and kind of cancel out the uncertainty if you will.

MS. HART: There are some tradeoffs that could be made that way. I think it's harder to talk about those when you're saying that you're doing a PRA and you're evaluating it in the best-estimate plus uncertainty. But there are -- you have to look at the actual analysis and determine if it's sufficient for the purpose.

MEMBER PETTI: Thanks.

MS. HART: And it's kind of a little bit of a philosophical discussion.

MEMBER PETTI: Yes.

MS. HART: And I think it is also difficult because, as we had talked about, these do not provide the source terms. We don't have the scenarios in front of us. In this methodology report we don't have the output scenarios -- I mean, output source terms that go to those scenarios and then passing them through to consequence analysis. I mean, we did see examples. They provided examples. But seeing that whole -- the whole thing is -- provides a different perspective on it.

MEMBER PETTI: You'd anticipate audits because some of the details probably won't be in the actual FSAR. Let's not even talk about PSAR because some of the stuff you won't see until FSAR.

MS. HART: Right. So of course if you look at the guidance in the TICAP, which is the technology-inclusive content of applications, which is for licensees -- or for applicants, excuse me, that want to use the LMP methodology and how they report it in their safety analysis reports, there's a general kind of -- I won't say expectation, but a general thought that a lot of this information would be available for audit. It would be in the supporting calculations. But the summary and the information in the safety analysis report should be sufficient to give you the idea of what they have done.

And there's -- that's to be seen as well. I mean, we have applications right now and the construction permits, but those of course are with preliminary information. So it doesn't necessarily include all aspects we would expect to see in a final safety analysis report.

MEMBER DIMITRIJEVIC: Michelle, this is Vesna Dimitrijevic. I was wondering, can you tell us a little about those examples they provided? When did they start and when did they finish? Did they start with the sequence and then go through source term and the consequences? What type of examples did they provide?

MS. HART: It was just the source term development so it did not really talk about how they developed the sequence. And it was very -- I am trying to remember. Of course I don't have them in front of me. It was very specific to like a specific event.

MEMBER DIMITRIJEVIC: Well, that's what the (audio interference) --

MS. HART: That doesn't help at all, but --

MEMBER DIMITRIJEVIC: Yes. All right. Well, did they also took those source terms through the consequences analysis which we discussed earlier today?

MS. HART: Not in the context of this review, no.

MEMBER DIMITRIJEVIC: All right. So that was just some specific event to the source terms?

MS. HART: Correct. And what I was really looking at to a certain degree was, well, what does the output look like and does it provide the kind of information that would be required by the consequence analysis? I wanted to see that particular aspect of it. So I didn't go deep into detail, like how did they model pool scrubbing or anything like that in the example calculations.

MEMBER PETTI: I think, Vesna, the trial calculation report from Argon is very instructive, I think, to see all the pieces. What wasn't done, which is what I think you're worried about, like from a PRA perspective is there's a point at which the source term meets the event tree and there's just so many, you've got to kind of roll up the events to some sort of master event that you think is bounding and then you can do the source term. And that's where the rubber meets the road and that's where --

MS. HART: Right, and that is not part of the methodology. It's that interface between them.

MEMBER PETTI: Yes.

MS. HART: It's not part of either --

MEMBER PETTI: Right.

MS. HART: -- analysis per se.

MEMBER PETTI: It's done. Yes.

MR. ANZALONE: And this is Reed Anzalone from the staff. I want to weigh in on that. That is, we're seeing the whole -- in the construction permit application we're seeing it all from soup to nuts. LBE selection through event sequences and quantification and down to the source terms and consequences. All the pieces are there.

MEMBER PETTI: So, and just to confirm, the CP follows TICAP RRCAT in terms of the structure, the way it's laid out?

MS. HART: For the most part.

MEMBER PETTI: For the most part?

MR. ANZALONE: With a couple of tweaks.

MEMBER PETTI: So it will also be the first time to go through with that new structure because --

MS. HART: Correct?

MEMBER PETTI: Yes.

MS. HART: And the use of audits to confirm the information in a different way than we have done it in the past. Or I won't say that different, but much more focused.

Okay. Next slide, please? As I had stated, or as TerraPower has also stated, they have not made the source term EM adequacy decision yet. And this work is planned to be completed prior to submission of an operating license application. We find this information is sufficient for the methodology development stage given the relevance of the methodology at the construction permit stage.

Next slide, please? So to get to the limitations and conditions, Topical Report, Section 8.2 proposed six limitations on the use of the topical report methodology. The staff agreed with the majority of the limitations as written and carried them forward to the safety analysis report limitations and conditions. NRC staff did not find Limitation 5 listed in the topical report to be necessary, so we did not carry it forward. Safety Analysis Limitations and Conditions 6 through 8 were imposed by the staff.

On this slide you see Limitations 1 through 3, which are all related to the preliminary Natrium design information that was used in the development of the EM and they're the same as written in the topical report.

Next slide, please? Limitations and Condition 4 is related to the applicability of the sodium pool scrubbing model to the assumed Natrium operating and accident conditions and is the same as was written in the topical report.

Limitation and Condition 5 was the Topical Report Limitation 6 and is related to future work to complete the code V&V for the evaluation model.

And Limitation and Condition 6 was imposed by the staff to ensure that the computer code user inputs are documented and justified. For example, there are several different models in some of these codes that the user can choose and so we wanted them to provide that in their final documentation of the analysis so that we know what they've used. Or there may be user inputs like the range of aerosol sizes or something like that. We wanted to understand exactly what they used because it's not specified specifically in the topical report.

Next slide, please? The staff imposed Limitation and Condition 7 to state that the evaluation model is to be used in LMP-based license applications or other best-estimate plus uncertainty analyses for applications using another process. For example, if they wanted to use this methodology to develop a mechanistic source -- I mean, to develop a source term for a maximum hypothetical accident, they would have to justify its use and say how they're using it. So the phenomena should be the same, but how they're using it is not described in this topical report for a maximum hypothetical accident. So we thought this was an appropriate limitation to add.

Next slide, please? Limitation and Condition 8 was imposed by the staff to ensure that the EMDAP steps are completed and any additional work related to the source term EM closure models are done. I say steps completed in a qualitative sense. They're not following the Reg Guide specifically or verbatim, however they did describe several areas where they're doing some ongoing work related to experimental data or justifying the models that they're using.

And we wrote this limitation and condition to capture that information that was described in the topical report as ongoing. There's no additional tests that we thought that they -- or that we described that they needed to do or any additional work in that area. But this is just to capture the work that they said that they're already doing.

Next slide, please? And so the overall conclusion. We do find that the methodology subject to limitations and conditions is an acceptable approach for develop mechanistic source terms for the prospective Natrium reactor construction permit or operating license applications under 10 CFR Part 50.

Are there additional questions?

CHAIR ROBERTS: It looks like we're out of questions for the open session. So at this point in the agenda we go out for public comments. So if anybody either in the room here or on Teams would like to make a comment for the record, go ahead and raise your hand.

I'm sorry. Before we go there, I just noted that Vicki had a question. So before we go to public comments, Vicki, you wanted to make a comment?

MEMBER BIER: Yes. This is not really a comment on today's presentations. This is just a comment that I tried to make yesterday that I'll make now so that we get it on the record in open session.

I had no real criticisms of what was presented yesterday based on sort of conservatisms or adapting models that were maybe only partially relevant to the situation that was being modeled.

The only comment that I really wanted to share on that is that while those analyses might be conservative with respect to overall risk level, there may not be assurance that they are conservative when it comes to, for example, identifying risk-significant SSCs. Because if the dominant contributor to risk is overly conservative, you may identify risk-significant SSCs for that contributor that may not actually be the most important SSCs for what is really driving the risk at a particular facility.

So I don't think that directly relates to whether there are problems with the current topical report, but I wanted to raise that comment. And if there are responses either from the staff or the applicant, I'd be happy to hear those responses as well. Thank you.

MR. ANZALONE: This is Reed Anzalone from the staff. I don't know that I have a specific response to the comment, but I certainly do appreciate it and I think that's something we're trying to keep in mind as we're reviewing the various applications.

MEMBER BIER: Thanks.

CHAIR ROBERTS: Okay. Thanks, Vicki.

So now we're back for public comments. I see that Dr. Lyman has his hand up.

So, Ed, if you want to un-mute yourself and state your name and affiliation and make your comment.

DR. LYMAN: Yes, this is Edwin Lyman with the Union of Concerned Scientists. Can you hear me okay?

CHAIR ROBERTS: Yes.

DR. LYMAN: Great. Yes, so a couple of comments: So in regard to the first session, I didn't really hear a good response to Dennis Bley's observation regarding what conservative meteorological conditions means. And it seems illogical because in order to assess whether these generic -- the generic met data is actually conservative for a specific site you would have to compare the consequence analysis to, one, based on met data that was done for the specific site. And if you've done that, then why would you use the generic data in the first place? So it seems pretty confusing.

Then with regard to the second presentation I didn't really hear a clear statement. There was some discussion of the comparison of the Natrium functional containment to -- and other structures to historical fast reactor containments and it was a little unclear to me how that actually plays out.

But I just wanted to read for the record -- this is from an NRC document, which unfortunately is undated, but it is called Clinch River Breeder Reactor Tutorial. And it states that a liquid metal fast breeder reactor containment, like a light water reactor containment, is designed to accommodate without exceeding design-basis rates the pressure and temperature conditions of design-basis accidents.

So first of all, unless you can show that the Natrium physical containment, for what it's worth, meets those conditions, then I can't see how you can say it's comparable to historical standards.

And in addition, we know that containment structures in addition to meeting the design-basis accident functions provide substantial protection against beyond-design-basis accidents. And so that's another incidental need or use of a physical containment structure. And again it's not clear that that -- the extent to which that additional defense-in-depth would be provided by the functional containment.

And finally, it was raised, the question of hypothetical core disassembly accidents. And historically the NRC's position was you don't need a physical containment to address that as a design-basis accident, but you have to show or do work to show that the probability of such an event is very low. And so I would think that the paragraph that Dr. Petti described about the relationship to historical issues needs to be more than just a paragraph, but actually that full demonstration of why HCDAs should be excluded from the excluded from the design-basis and to be consistent with the NRC's previous positions.

So those are my comments. Thank you.

CHAIR ROBERTS: Thank you, Dr. Lyman.

Any other members of the public who would like to make a comment for the record?

(No audible response.)

CHAIR ROBERTS: Okay. And seeing none, the next part of the open agenda is committee discussion, where to go with this. Clearly as I observed yesterday, we still have the closed discussion yet to go, so that's going to inform overall what we're doing next. But I still wanted to poll the members on your thoughts.

I guess, Bob, I'll start with you on the consequences of radiological consequences TR. What are you thinking?

MEMBER MARTIN: Pretty straightforward. As you said, we might have some unique insights coming from the closed session, but going in position, it's just a summary -- or, but --

CHAIR ROBERTS: Okay. That's kind of what I was thinking, too.

Anybody, different thoughts?

(No audible response.)

CHAIR ROBERTS: Okay. That seems like that's pretty clear.

So then on the source term we have I think a lot of discussion coming up in the closed discussion. And I think, Dave, you've already alluded to you're inclined to further pursue a letter report.

The committee schedule has some time in May to discuss a potential letter report. And so my thought, and I guess I'll get to Bob and Scott, your thoughts, is to go ahead and knock off the summary reports in the April ANP session? So we could just get that off the agenda for May. May is a very busy month in the full committee agenda. And so we can write those three up in terms of the summary reports. Discuss them then. Then we can get those off the agenda for May.

And then for the May session, Dave, I guess probably want to hear some more of the closed session as to what we would like to have presented by the applicant and the staff in May. So I guess we can defer that discussion, whether there would be time with the agenda for that if we decide during closed session to have presentations from the applicant or the staff.

MEMBER PETTI: Yes.

CHAIR ROBERTS: Great. So I don't know if you have any more to say on that at this point?

MEMBER PETTI: No, that's fine. Let's

come back in the closed session where we maybe get some answers on what we'd like to hear in the full committee. Obviously last, but --

MEMBER HALNON: One point I want to make for those writing that summary for us, we need to make sure we emphasize the CP level of detail that we talked about and also that these are methodologies and not the end-all. We still have operating license-specific data to come. So we don't want to give the impression that we're approving the -- or have reviewed the final design aspect of the reactor yet. So those two things I think we need to make sure that the summary report is very clear on.

CHAIR ROBERTS: Okay. Thanks, Greg.

So anybody have anything else they'd like to discuss here in the open session before we close?

(No audible response.)

CHAIR ROBERTS: Seeing none, I wanted to thank both the applicant and the staff for their presentations. They were certainly very helpful and putting together for relatively complex topical reports and distilling them down to the key points.

I mentioned in the closed session yesterday, but I want to mention in the open session, really appreciate the folks at TerraPower who got up at whatever time they had to get up to be available at 5:30 in the morning Pacific Time for these sessions. We had a lot to cover. It was good to be able to have the full day available. So I would express my appreciation for that.

Other than that, I'd like to close the open session. It's now 12:09 -- 12:10. So let's go ahead and say quarter after 1:00 Eastern, 1:15 Eastern to start the closed session. With that, the open session is adjourned.

(Whereupon, the above-entitled matter went off the record at 12:09 p.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

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

TP-LIC-PRSNT-0042

Natrium reactor is a TerraPower & GE Hitachi technology

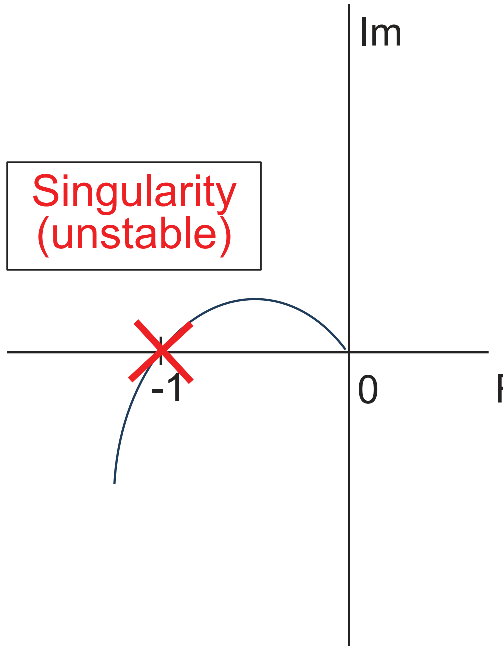
Topical Report Purpose

- 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

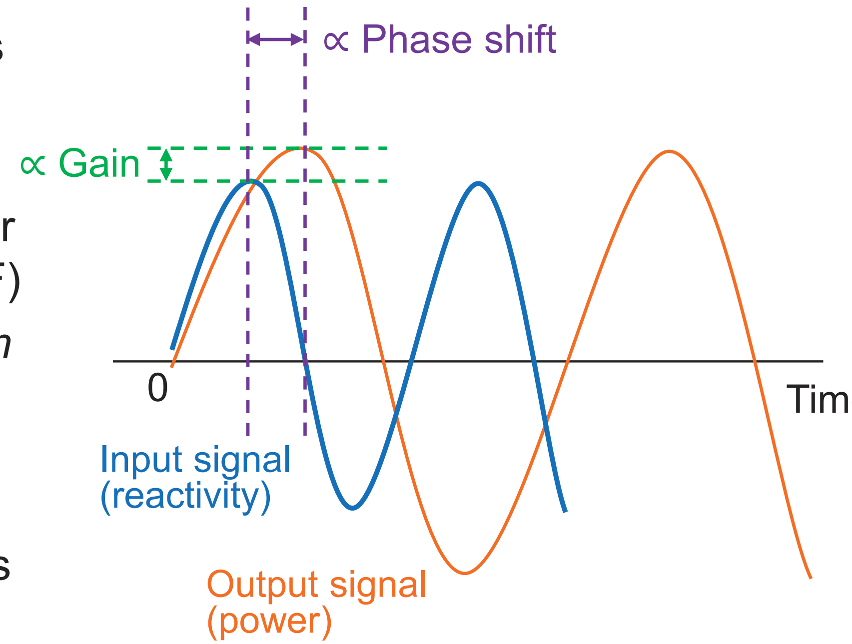
- Natrium Principal Design Criterion (PDC) 12 states:
  - The reactor core; associated structures; and associated coolant, control, and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable radionuclide release design limits [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)



SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

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



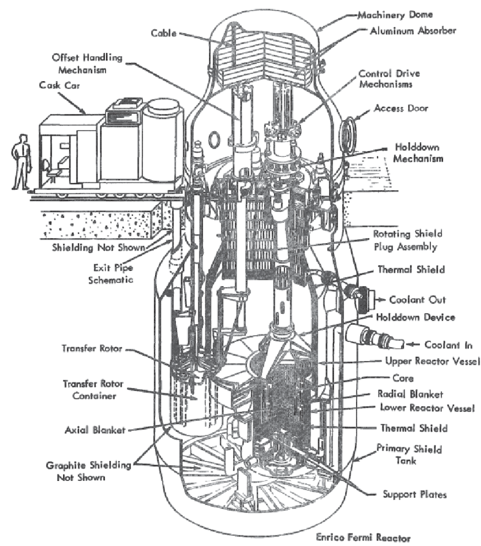
Methodology Overview

Benchmark: Fermi-1 Oscillator Rod Measurements

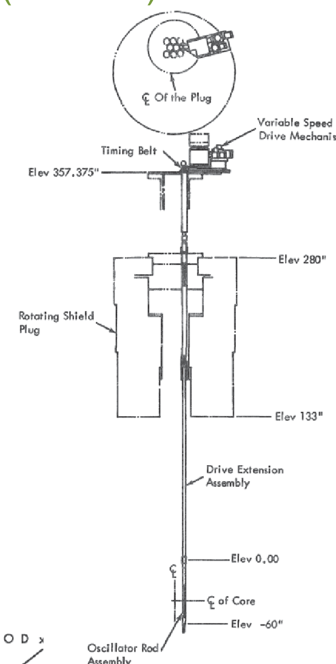
- Fermi-1 was a commercial power reactor (1960s)
  - Similar to Natrium reactor: Metal fuel, sodium coolant, fast spectrum, several hundred Megawatt power level
- Oscillator rod measurements performed during startup testing of the facility
  - Applied a sinusoidal reactivity input at frequencies from 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

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

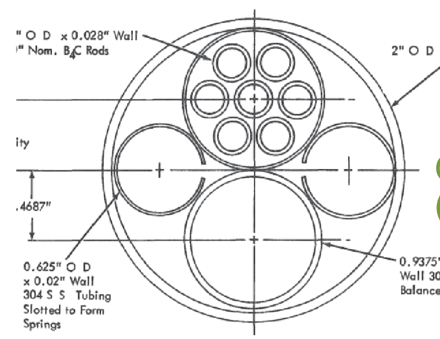
Reactor vessel



Oscillator rod (YZ view)



Oscillator rod (XY view)



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.

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

All Quantified Events by Radiation Source

In-Vessel Events

Events w/o Release

Tools: System Model (SAS4A/SASSYS-1) and elel Performance Model
- Time-at-temperature no failure (TATNF) criteria met

OR
- Fuel performance shows no release

Clad Failure →

Events w/ Release

Tools: System Model or Mechanistic Evaluation, Fuel Performance Model, Mechanistic Source Term, Atmospheric Dispersion

- Events with fuel failure predicted

Ex-Vessel Events

Events w/o Release

Tools: Mechanistic Evaluation and Fuel Performance Model

- Release prevented from selected Radiation Source by an identified barrier
- Fuel Performance model used for fuel

1st Barrier Failure →

Events w/ Release

Tools: Mechanistic Evaluation, Fuel Performance Model, Mechanistic Source Term, Atmospheric Dispersion

- Fuel handling events
- Radionuclide containing SSCs

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

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

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

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

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

ENCLOSURE 5

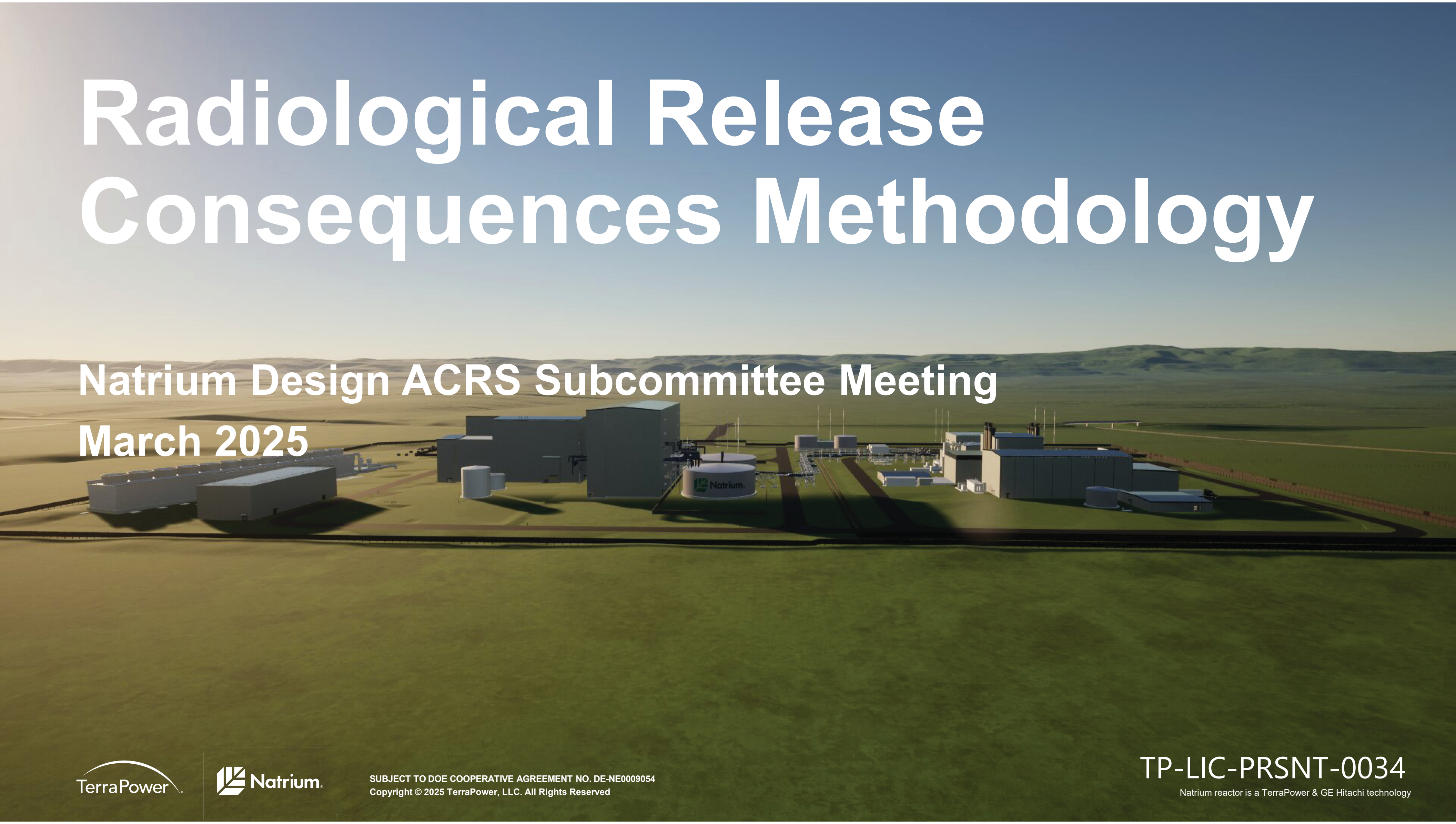
“Radiological Release Consequences Methodology”
Presentation Material – Open Meeting

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

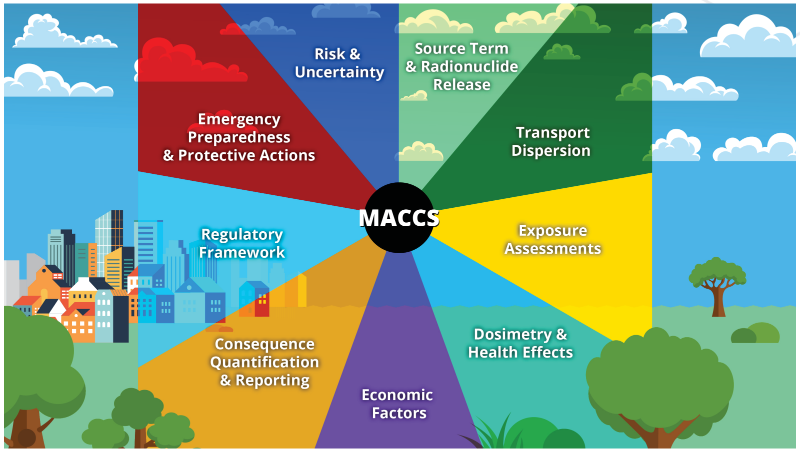
Methodology Objectives

- 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

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?

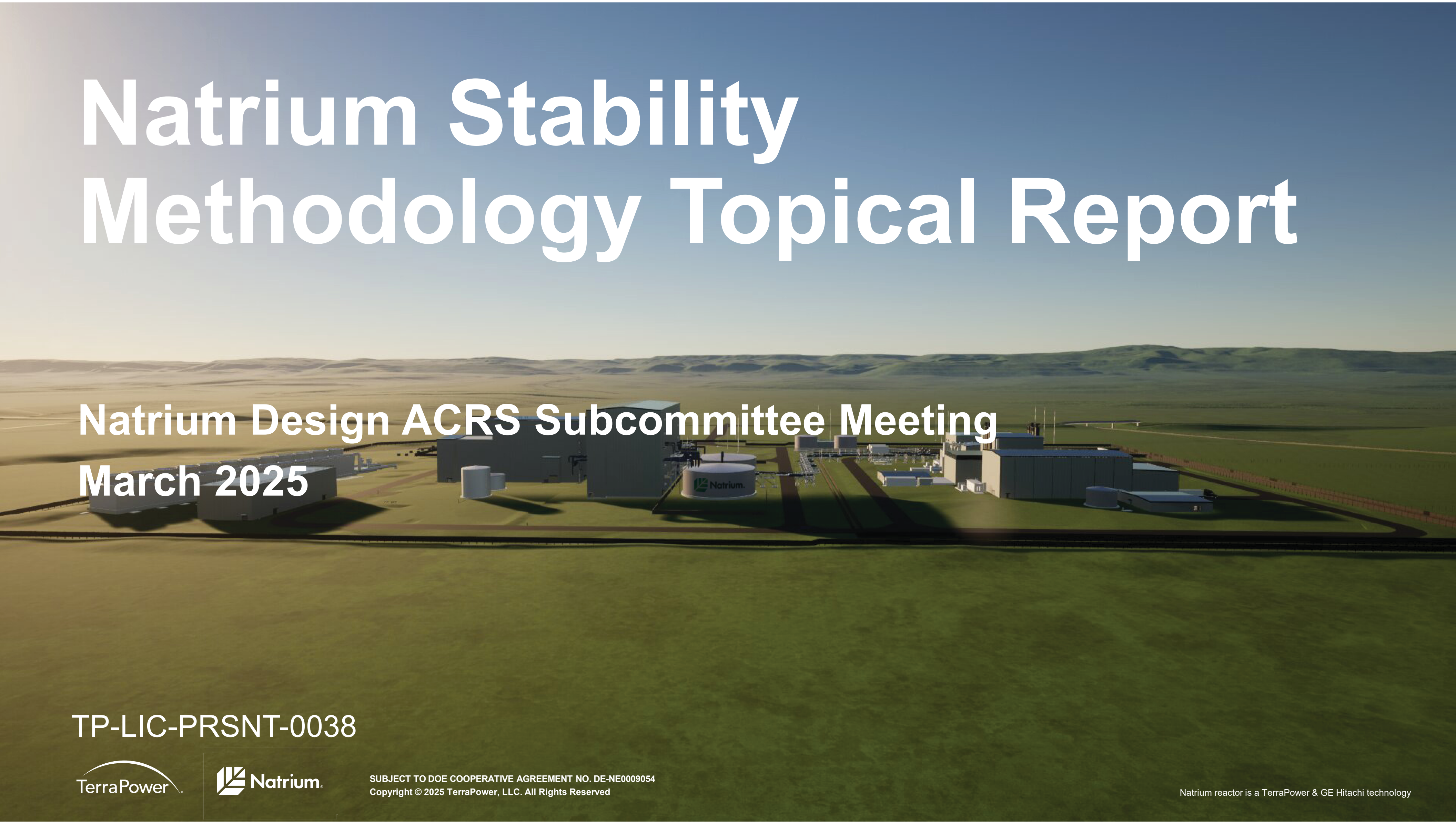
Acronym List

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.

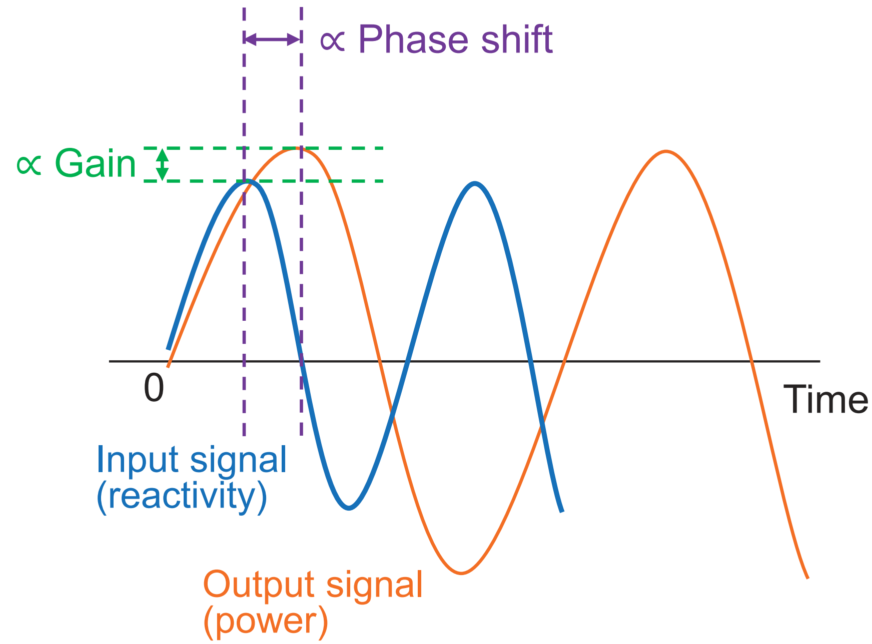
Portions of this presentation are considered proprietary and TerraPower, LLC requests it be withheld from public disclosure under the provisions of 10 CFR 2.390(a)(4).

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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Methodology Overview

Overall Evaluation Approach

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

[[

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- 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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Methodology Overview

Uncertainties Treatment

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]](a)(4), ECI

Methodology Overview

Uncertainties Treatment

[[

]](a)(4), ECI

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).

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

SAS Biasing, HCFs and HPR

Nominal Case with nominal input → SAS input perturbation with biases → SAS calculation → Safety HCF with HPR applied on SAS limiting results → FoMs with uncertainties compared to criteria

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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

TerraPower Natrium

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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

Natrium reactor is a TerraPower & GE Hitachi technology

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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

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

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 TerraPower NAT-9391, “Radiological Release Consequences Methodology Topical Report,” Revision 0

ACRS Subcommittee Meeting

March 19, 2025

Agenda

- Review staff
- Review chronology
- Overview of topical report (TR)
- Relationship to other TerraPower TRs
- Evaluation models (EMs)
- Limitations and Conditions
- Conclusions

Review Staff

- Michelle Hart - Senior Reactor Engineer, Office of Nuclear Reactor Regulation (NRR)/Division of Advanced Reactors and Non-power Production and Utilization Facilities (DANU)/Advanced Reactor Technical Branch 2 (UTB2)
- Zach Gran – Reactor Scientist (Severe Accident), NRR/DANU/UTB2
- Reed Anzalone – Senior Nuclear Engineer, NRR/DANU/UTB2
- Mike Mazaika – Physical Scientist (Meteorologist), NRR/Division of Engineering and External Hazards/External Hazards Branch
- Keith Compton – Senior Reactor Scientist, Office of Nuclear Regulatory Research (RES)/Division of Systems Analysis (DSA)/Accident Analysis Branch (AAB)
- Kyle Clavier – Detailed to RES/DSA/AAB
- Deion Atkinson – Project Manager, NRR/DANU/Advanced Reactor Licensing Branch 1

Review Chronology

- November 2023: TerraPower submitted TP-LIC-RPT-0005 “Radiological Release Consequences Methodology Report,” Revision 0 (ML23311A139) for NRC review
- December 2023: The NRC staff found that the material presented in the TR provides technical information sufficient for a detailed technical review (ML23333A070)
- May through June 2024: NRC conducted a regulatory audit (ML25024A041)
- July 2024: TerraPower submitted a revision to the TR, which was renumber as NAT-9391, Revision 0 (ML24208A181)
- February 2025: NRC staff issued the draft safety evaluation (ML25057A290)

Related TerraPower submittal:

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

TR Overview

- This TR is intended for use in Natrium license applications under Part 50 using the Licensing Modernization Project (LMP) approach
  - Methodology to determine radiological consequences given a source term
  - Event specific source terms are input
- No specific calculations are provided or approved for use
- The TR provides:
  - Licensing Basis Events (LBE) EM
  - Design Basis Accident (DBA) EM
  - Control Room Habitability (CRH) EM
  - Appendix to adapt the LBE EM for use in Emergency Planning Zone (EPZ) sizing

Relationship to Other TRs

- NAT-9392 (ML23223A235), “Radiological Source Term Methodology Report”
  - Source terms developed by use of NAT-9392 can be used as input to the Radiological Release Consequences methodology
- NAT-3056 (ML24304B034), “Plume Exposure Pathway Emergency (PEP) Planning Zone Sizing Methodology”
  - Consequence results are used in the PEP EPZ sizing analyses

Licensing Basis Event EM

- Objective of the LBE EM
  - Determine through a probabilistic approach, the radiological consequences of an LBE for which a representative source term has been determined
  - LBE EM is intended to be used by the applicant in the NEI 18-04 LMP methodology which uses information from a facility-specific probabilistic risk assessment (PRA), including consequences
- TR section 3.4 states that the LBE EM uses the MELCOR Accident Consequence Code System (MACCS) computer code.
- NRC staff reviewed inputs and model parameters, technical rationale, risk metrics, and pertinent details associated with MACCS model execution for the purposes of evaluating radiological release consequences.

LBE EM: PRA Standard Considerations

- Because the LBE EM addresses PRA-related consequence analysis information needs for the LMP methodology, the NRC staff used information in RG 1.247 (ML21235A008) on PRA consequence analysis to aid in the review and evaluate completeness of the methodology.
- The subject areas of the non-light water reactor (NLWR) PRA standard for consequence analysis are as follows:
  - Radionuclide release characterization
  - Site characterization
  - Meteorological data analysis
  - Atmospheric transport and diffusion analysis
  - Protective action analysis
  - Dosimetry
  - Health effects analysis
  - Economic factors
  - Conditional consequence quantification

LBE EM: Radionuclide Release Characterization

- RG 1.247, section C.1.3.17 states the objective of radionuclide release characterization is to identify the attributes of radiological release needed to evaluate radiological consequences
- NRC staff review of the information determined that:
  - The isotope sensitivity method is acceptable because it ensures all risk-significant radionuclides are identified by reviewing the treatment of radiological half-life, biological hazard, and relative abundance of the radionuclides in the core.
  - The adaptive plume algorithm is acceptable because it would likely result in conservative dose results and results have low sensitivity to the number of plume segments.

U.S.NRC United States Nuclear Regulatory Commission *Protecting People and the Environment*

LBE EM: Site Characterization

- RG 1.247, section C.1.3.17 states the objective of site characterization is to provide information on the population distribution and patterns of land use and land cover in the vicinity of and region of a site to a distance of 80 km, or 50 miles.
- NRC staff determined that the LBE EM treatment of site characterization is acceptable because:
  - The use of uniform population distribution will be shown to be conservative;
  - Land use information has a negligible impact on the calculation of dose quantities for LMP; and
  - The approach is consistent with previous NRC staff use of the MACCS code in reactor safety studies.

LBE EM: Meteorological Data Analysis

- RG 1.247, section C.1.3.17 states the objective of meteorological data analysis is to evaluate and select the meteorological data used for atmospheric transport and diffusion analysis.
- LBE EM requires input meteorological data including wind speed and direction, stability category, rain rate, and mixing height that is representative of weather conditions at the Natrium power plant over the most limiting year.
- The TR states that in lieu of site-specific meteorological data, the user may opt to use a generic meteorological data file based on the Electric Power Research Institute (EPRI) Advanced Light Water Reactor Utility Requirements Document (URD) if the data is shown to be conservatively representative of the site.

LBE EM: Meteorological Data Analysis

- NRC staff review of TR information determined that:
  - The LBE EM adequately identifies the meteorological data needed to characterize atmospheric dispersion for the site;
  - The use of generic meteorological data from the EPRI URD is acceptable if shown conservatively representative of the site; and
  - The use of the URD generic meteorological data in the LBE EM is similar to the uses described in the URD, with respect to completeness of the data set
- Limitation and Condition 1 is imposed, in part, to ensure that use of the URD generic meteorological data is limited to sites within the contiguous U.S., consistent with the basis for the data.
- Does not constitute approval of the use of generic data instead of site-specific data in future analyses when addressing relevant regulations, including 10 CFR 50.34. Applicants referencing this TR should consider how this methodology may need to incorporate additional information in order to satisfy the regulatory requirements.
- The use of random weather sampling to assess consequence uncertainty due to weather conditions is acceptable because it is consistent with guidance on radiological consequence analysis for NLWR PRAs in RG 1.247

LBE EM: Atmospheric Transport and Diffusion Analysis

- RG 1.247, section C.1.3.17 states the objective of atmospheric transport and diffusion analysis is to perform an evaluation that provides time dependent air and ground concentrations resulting from a release of radioisotopes
- NRC staff review of TR information determined that:
  - The LBE EM atmospheric dispersion modeling, including the specifics on use of the MACCS for atmospheric dispersion modeling, are acceptable because it is consistent with implementation in NRC-developed atmospheric dispersion codes used in reactor licensing analyses, as well as technical guidance for MACCS in NUREG/CR-7270 (ML22294A091)
    - Characteristics of the area and distance ranges under consideration
    - Nearfield effects, such as elevated releases of radioactive material
    - Building wake effects
    - Plume meander
    - Plume rise
    - Plume deposition based on wet and dry deposition

LBE EM: Atmospheric Transport and Diffusion Analysis

- NRC staff review of TR information determined that:
  - The use of the Gaussian plume segment model in MACCS is acceptable because it is based on the guidance contained in RG 1.145 (ML003740205) and RG 1.249 (ML22024A241); and
  - The LBE EM use of the MACCS CHRONC module to model long term exposure to radionuclides deposited on the ground is appropriate because it models the effects of weathering on the ground contamination concentration, as well as resuspension of the radionuclides to the atmosphere and is consistent with the risk analyses using the MACCS code as described in NUREG/CR-7270.
- Limitation and Condition 1 is imposed, in part, to ensure that use of the TR is limited to sites within the contiguous U.S., because the atmospheric dispersion models described in the accident-related guidance referenced are based on weather conditions that are expected in the contiguous U.S.

LBE EM: Protective Action Analysis

- RG 1.247, section C.1.3.17 states the objective of protective action analysis is to characterize the impact of mitigation measures such as evacuation, sheltering, relocation, and interdiction of land, food, or water on doses resulting from releases of radioisotopes.
- The LBE EM conservatively models no protective actions (e.g., evacuation or sheltering) to calculate dose at the EAB and for the individual risk of early fatality.
- NRC staff determined that the LBE EM modeling for short-term exposure without credit for protective actions is acceptable because it results in conservative dose results

LBE EM: Protective Action Analysis

- The LBE EM models the intermediate- and long-term phase protective actions such as land decontamination and condemnation based on reaching specified dose levels based on the Environmental Protection Agency (EPA) protective action guides (PAGs) to evaluate the individual risk of latent cancer from long-term exposure to radionuclides deposited on the ground.
- NRC staff determined that the LBE EM modeling of protective actions for long-term exposure is acceptable because it is consistent with the recommendations contained within NUREG/CR-7270 and EPA PAGs.
- The NRC staff will evaluate the modeling of dose reduction factors associated with occupancy of structures or vehicles, which are not described in the LBE EM, in its review of the analysis supporting a license application referencing the TR.

LBE EM: Dosimetry

- RG 1.247, section C.1.3.17 states the objective of dosimetry is to identify the analyses needed to estimate the dose to offsite populations, arising from airborne and deposited radioisotopes.
- NRC staff review of TR information determined that
  - The information on organs of risk is acceptable because it is consistent with reactor risk analyses using the MACCS code described in NUREG/CR-7270, as well as the guidance in RG 1.183 (ML23082A305) on use of Dose Conversion Factors (DCFs) from Federal Guidance Report (FGR) 11 and FGR 12 to calculate TEDE;
  - The information on the calculation of the risk of early fatality and risk of latent cancer fatality, including the parameter values listed in the TR tables, is acceptable because it is consistent with the reactor risk analysis using the MACCS code as described in NUREG/CR-7270;
  - The method for calculating dose is acceptable because all relevant short-term and long-term exposure pathways are identified and calculated considering inhalation dose, cloudshine, and groundshine consistent with guidance in RG 1.183 for estimating TEDE;
  - The calculation for the risk metrics is acceptable because the dosimetry is based on FGR 13, which is a recognized information source developed by the EPA as a resource for the federal government and reflects an age- and gender-averaged adult population; and
  - The modeling of the exposure periods is acceptable because it is consistent with the description in NEI 18-04 of the dose quantity to be compared to the LMP frequency-consequence target, the Quantitative Health Objective (QHO) figures of merit for early fatality risk and latent cancer fatality risk and is reasonable for the evaluation of the cumulative probability per plant-year of exceeding the 100 mrem TEDE at the site boundary as required described in the LMP.

LBE EM: Health Effects Analysis

- RG 1.247, section C.1.3.17 states the objective of health effects analysis is to assess the risk of early or latent health effects, either fatal or nonfatal, or both, arising from acute and chronic exposure to released radioisotopes.
- NRC staff review of TR information determined that the evaluation of health effects is appropriate because the list of cancer fatality sites in the human body is consistent with FGR 13, and the list of early fatality health effects is consistent with those identified in NRC reactor risk studies with consequence analyses as found in NUREG-1150 (ML120960691) as well as NUREG/CR-7270.

LBE EM: Economic Factors

- RG 1.247, section C.1.3.17 states the objective of economic factors PRA analysis is to assess the economic impact of releases of radioisotopes, including the economic impact of protective actions taken to limit exposure to released materials.
- The LMP methodology, as endorsed in RG 1.233 (ML20091L698), does not use economic factors or cost-benefit analysis to determine events, classify SSCs, or evaluate the adequacy of defense-in-depth, consistent with the requirements in 10 CFR 50.34 which it addresses.

LBE EM: Conditional Consequence Quantification

- RG 1.247, section C.1.3.17 states the objective of conditional consequence quantification is to integrate the models and data developed in the preceding technical elements to quantify results of interest
- NRC staff review of TR information determined that:
  - The use of MACCS in the LBE EM is consistent with the purposes for which MACCS was developed and is well within the limits of the code’s applicability;
  - The MACCS model inputs and accompanying data files and specifications are acceptable for use in the LBE EM because they are consistent with sample problems supplied with MACCS and NUREG/CR-7270;
  - Uncertain parameters that contribute significantly to radiological consequences were analyzed and conservatively bounding values were prescribed in the LBE EM. and
  - The LBE EM weather sampling approach is acceptable because it addresses the uncertainty in the weather in combination with the variability in meteorological conditions, consistent with the NRC’s approach in probabilistic consequence analyses.

LBE EM Conclusions

- The TR methodology provides estimates of LBE radiological consequences for use in the LMP methodology consistent with the non-light water reactor radiological consequence analysis PRA elements detailed in section C.1.3.17 of RG 1.247.
- The LBE EM consequence analysis results when used in the LMP are sufficient to address the analysis requirements in 10 CFR 50.34(a)(4).
- The identification of MACCS to evaluate PRA consequences is appropriate because it is an NRC-developed, widely used PRA analytical tool specific to consequence analysis.

Design Basis Accident EM

- The objective of the DBA EM is to describe the methodology that would be used by a future applicant to calculate the highest TEDE received over any 2-hour period by a receptor on the EAB and the 30-day TEDE received by a receptor at the outer LPZ boundary, considering contributions due to inhalation and submersion dose
- The dose criteria are in 10 CFR 50.34(a)(1)(ii)(D)(1) and 10 CFR 50.34(a)(1)(ii)(D)(2) which specify a limiting dose of 25 rem TEDE for each DBA
- The NRC staff review determined that the DBA EM performs calculations consistent with the guidance contained in RG 1.183 for radiological consequence analysis assumptions and inputs

Control Room Habitability EM

- The objective of the CRH EM is to determine the dose consequences required to demonstrate habitability in the CR in conformance with Natrium PDC 19, which states in part that "[a]dequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem total effective dose equivalent, as defined in § 50.2 for the duration of the accident"
- The specific dose consequences calculated in the CRH EM are the 30-day TEDE dose received by a CR receptor considering inhalation and submersion dose, as well as gamma radiation shine from airborne radionuclides external to the CR, built up on filtration equipment and held in a compartment before release to environment

Control Room Habitability EM

- The NRC staff review determined that:
  - The methods to calculate the inhalation and submersion doses are consistent with the discussions contained in the DBA EM. The CRH EM performs calculations consistent with RG 1.183 guidance for calculating inhalation and submersion doses and is therefore acceptable.
  - The CRH EM describes a proprietary method for calculating shine dose received by control room operators
  - The CRH EM is acceptable because the method produces integrated CR dose results that include inhalation, submersion, and shine pathways
  - NRC staff will evaluate the acceptability of the specific methods used to calculate release-specific radiological source terms, CR atmospheric dispersion factors, and modeling of the CR used as input to the CRH consequence analysis during the review of an application that references this TR and implements the CRH EM

Appendix: Adapting the LBE EM for EPZ Sizing

- TR section 8, “Appendix - Adaptation of Licensing Basis Event Evaluation Model to Emergency Planning Zone Sizing,” describes minor changes to the LBE EM for use in the TerraPower PEP EPZ sizing methodology provided in TR NAT-3056, which is undergoing separate NRC review.
- The NRC staff determined that the adapted LBE EM described in the Appendix is acceptable because it provides dose results in the form of TEDE to an individual from a 96-hour exposure at various distances to address the PEP EPZ requirement in 10 CFR 50.33(g)(2).
- The LBE EM as adjusted by the TR Appendix provides information needed for the TerraPower PEP EPZ sizing methodology with respect to dose aggregation and evaluation of early deterministic health effects.

Limitations and Conditions

1. Application of the methodology in this TR with respect to the described deterministic and probability-based atmospheric dispersion modeling analyses and use of generic meteorological data is limited to sites within the contiguous United States unless technical justification for their applicability is provided.
2. The conclusions reached in this SE are not valid if a process other than that described in NEI 18-04 is used to perform the Natrium safety analysis.

Overall Conclusions

- NRC staff determined that the TR, subject to the limitations and conditions in the SE, provides an acceptable approach to develop analyses to aid in the determination of site-specific radiological release consequences for the proposed Natrium reactor designs.
- The NRC staff found that the discussion of the radiological consequence analysis PRA element in RG 1.247 was useful to ensure the completeness of the review of the LMP-related analysis methodology (LBE EM)

Acronyms

- CR – Control Room
- CRH – Control Room Habitability
- DBA – Design Basis Accident
- DCF – Dose Conversion Factor
- EAB – Exclusion Area Boundary
- EM – Evaluation Model
- EPA – Environmental Protection Agency
- EPRI – Electric Power Research Institute
- EPZ – Emergency Planning Zone
- FGR – Federal Guidance Report
- LBE – Licensing Basis Events
- LMP – Licensing Modernization Project
- MACCS – MELCOR Accident Consequence Code System
- NEI – Nuclear Energy Institute
- NLWR – Non-light water reactor
- NRC – Nuclear Regulatory Commission
- PAG – Protective Action Guides
- PRA – Probabilistic Risk Assessment
- PEP – Plume Exposure Pathway
- PDC – Principal Design Criteria
- QHO – Quantitative Health Objective
- RG – Regulatory Guide
- SE – Safety Evaluation
- SFR – Sodium Fast Reactor
- TEDE – Total Effective Dose Equivalent
- TR – Topical Report
- URD - Utility Requirements Document
- U.S. – United States

NRC Staff Review of TerraPower NAT-9392, “Radiological Source Term Methodology Report,” Revision 0

ACRS Subcommittee Meeting

March 19, 2025

Agenda

- Review staff
- Review chronology
- Topical report (TR) overview
- Relationship to other TerraPower TRs
- Regulatory requirements
- NRC staff review approach
- NRC staff review
- Limitations and conditions
- Conclusions

Review Staff

- Michelle Hart – Senior Reactor Engineer, Office of Nuclear Reactor Regulation (NRR)/Division of Advanced Reactors and Non-power Production and Utilization Facilities (DANU)/Advanced Reactor Technical Branch 2 (UTB2)
- Zach Gran – Reactor Scientist (Severe Accident), NRR/DANU/UTB2
- Reed Anzalone – Senior Nuclear Engineer, NRR/DANU/UTB2
- Stephanie Devlin-Gill – Senior Project Manager, NRR/DANU/Advanced Reactor Licensing Branch 1

Review Chronology

- August 2023: TerraPower submitted TP-LIC-RPT-0003 “Radiological Source Term Methodology Report,” Revision 0 (ML23223A235) for NRC review
- November 2023: Before accepting the TR for review, the NRC requested TerraPower supplement the information in the TR (ML23292A269)
- January 2024: TerraPower supplemented the TR by submitting Revision 1 of TP-LIC-RPT-0003 “Radiological Source Term Methodology Report” (ML24017A115)
- May through August 2024: NRC conducted a regulatory audit (ML24232A223)
- September 2024: TerraPower submitted a revision to the TR, which was renumbered as NAT-9392, Revision 0 (ML24261B944)
- February 2025: NRC staff issued its draft safety evaluation (ML25024A141)

Related TerraPower submittal:

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

TR Overview

- This TR is intended for use in Natrium license applications under Part 50 using the Licensing Modernization Project (LMP) approach
  - Methodology to determine event-specific source terms for use in a subsequent dose analysis
- No specific source term calculations are provided or being approved for use
- The TR provides the evaluation model (EM) used to determine mechanistic source terms (MSTs) for the proposed Natrium design

Relationship to Other TerraPower TRs

- NAT-9391, “Radiological Release Consequences Methodology Topical Report”
  - The source terms determined using NAT-9392 will be input into NAT-9391 consequence analysis methodology
- The source term methodology does not determine the licensing basis events (LBEs), design basis accidents (DBAs), or other quantified event scenarios that result in radiological source terms

Regulatory Requirements

- 10 CFR 50.34(a)(1)(ii) safety analysis comparison to 25 rem TEDE at the Exclusion Area Boundary (EAB) and the Low Population Zone (LPZ)
- 10 CFR 50.34(a)(3)(i) as it relates to the approved Natrium PDC 19 control room habitability dose criterion of 5 rem TEDE
- 10 CFR 50.34(a)(4) as it relates to the evaluation of the design of SSCs
- 10 CFR 50.34(b)(3) as it relates to the operating license (OL) requirement to provide the kinds and quantities of radioactive material expected to be produced in the operation of the facility
- 10 CFR 50.33(g)(2)(i) as it relates to plume exposure pathway emergency planning zone (EPZ) sizing

NRC Staff Review Approach

- Source term related guidance
  - Regulatory Guide (RG) 1.183 "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," Revision 1
    - Position 2, "Attributes of an Acceptable Accident Source Term," as applicable
  - Policy considerations
    - SECY-93-092 with respect to mechanistic source terms for non-light water reactors (non-LWRs)
    - SECY-18-0096 with respect to functional containment performance criteria for non-LWRs

NRC Staff Review Approach

- RG 1.247 “Acceptability of Probabilistic Risk Assessment Results for Non-Light-Water Reactor Risk-Informed Activities”
  - Section C.1.3.16 "Mechanistic Source Term Analysis Probabilistic Risk Assessment Element"
  - As described in NEI 18-04, the LMP methodology uses information from a facility-specific PRA, including MSTs
- NRC staff used the information in the non-LWR PRA standard’s MST analysis element as an aid
- NRC staff did not evaluate the acceptability of the Natrium PRA as part of its review of this TR

NRC Staff Review Approach

- First time an MST methodology is provided in the context of the Evaluation Model Development and Assessment Process (EMDAP) as a guideline
- RG 1.203, "Transient and Accident Analysis Methods"
  - NRC staff's review of the TR methodology considered the guidance on EMDAP, with a focus on the modeling of radionuclide transport and retention phenomena to provide MSTs for use in license applications

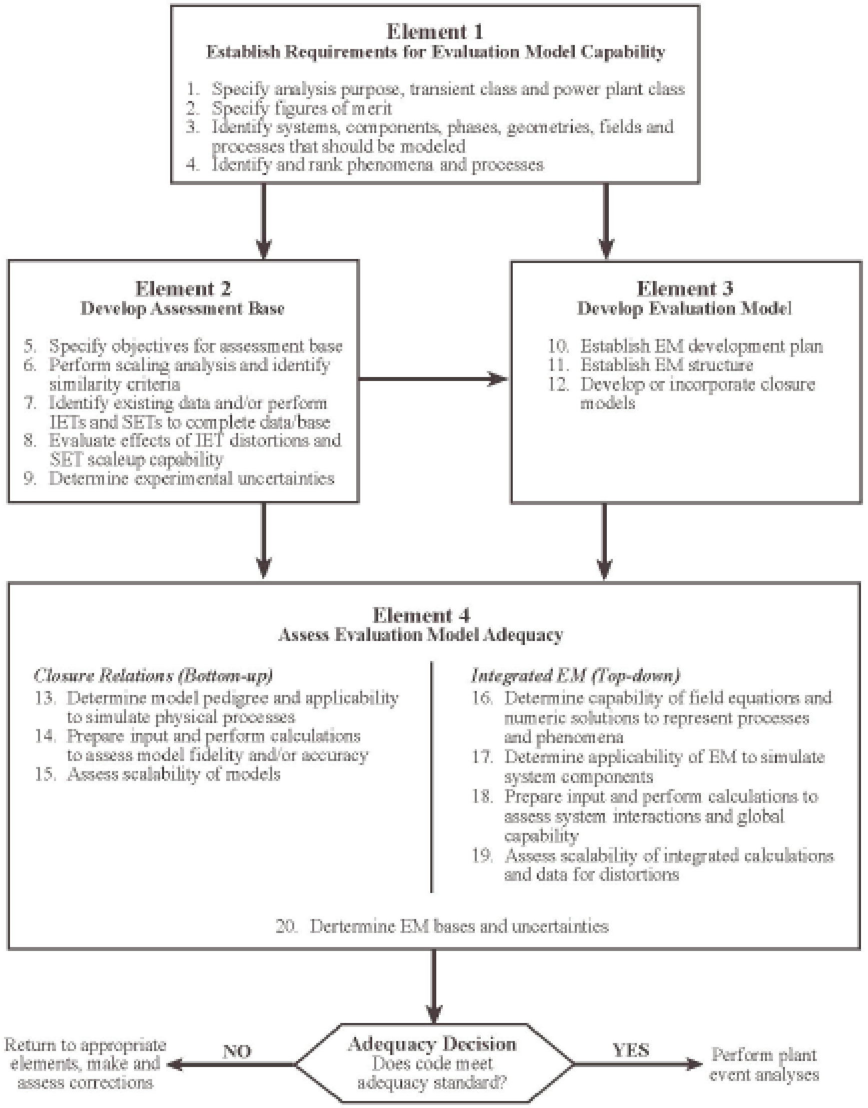

Figure 1. Elements of Evaluation Model Development and Assessment Process (EMDAP)

RG 1.203 Fig. 1

Overview of EMDAP

- The EMDAP consists of four main elements, including determining the requirements of the EM, developing an assessment base, developing the EM, and assessing EM adequacy
- Each element is also broken into component steps
- Adequacy decision and iteration

NRC Staff Review

- Use of EMDAP for determination of MST
- EMDAP elements
- Closure models

Use of EMDAP for Determination of MST

- TerraPower stated they considered the EMDAP guidance as industry best practice in methods development, but TerraPower does not intend for the source term EM to meet verbatim conformance with RG 1.203
- NRC staff determined that the TR use of EMDAP guidance in RG 1.203 is appropriate for describing the framework of a source term methodology because allows the NRC staff to understand:
  - the use of analytical tools in determining the radiological source term
  - the methodology assessment of the source term EM
  - how the upstream and downstream processes relate to the source term EM

Source Term EM Capability

- Analysis Purpose
  - Source Term EM outputs are MSTs intended for use in LMP-based license applications or other best-estimate plus uncertainty analyses
  - NRC staff imposed a limitation and condition related to this
- Figures of Merit (FOMs)
  - Determined to be consistent with the dose criteria described in the regulations and for LMP
- Design Information
  - TR describes the preliminary Natrium design information used to develop the EM and provides 3 limitations on the use of the TR related to design information

Source Term EM Capability

- Phenomena Identification and Ranking Table (PIRT)
  - The TR used a PIRT for identification of phenomena and barriers important to the development of MSTs for the proposed Natrium reactor design
    - Dose-based FOMs from EMDAP Step 2 are used in the ranking
  - NRC staff determined that the PIRT is acceptable for the methodology scope because:
    - Using a PIRT is consistent with RG 1.203 EMDAP Step 4
    - Source term phenomena and ranking are appropriate for the scenarios considered in the EM because they are consistent with the proposed Natrium design and past sodium fast reactor (SFR) operating experience

Source Term EM Assessment Base

- The source term EM assessment base is used to validate calculational devices or codes used as part of the EM and may consist of a combination of legacy experiments and new experiments
- NRC staff determined that the methodology provided in this TR section is consistent with guidance for RG 1.203 EMDAP Element 2
  - TR appropriately describes the process for determining the phenomena of interest and describes the process for obtaining existing experimental data or using conservative approaches to address concerns with uncertainty for phenomena relevant to MST
  - Ongoing work is planned to be completed prior to submittal of an OL application, and relevant information will be included in a future licensing submittal
    - NRC staff imposed a limitation and condition

Source Term EM Structure

- The TR discusses the use of RADTRAD and other computer codes
- NRC staff audited documentation for each computer code cited
    - Computer codes used in the EM address MST phenomena and are fit to the purpose
- NRC staff verified the inputs into this source term EM and how the computer codes account for the MST phenomena identified in EMDAP Element 1
- NRC staff review determined that the process delineated in TR section 4.1 and 4.2 is acceptable because it provides sufficient information to understand the computer codes and computer code capabilities consistent with the EMDAP guidance

Source Term Characterization

- NRC staff determined that the information contained in TR section 4.2.5, and the referenced documents, justifies the method of identifying risk-significant radionuclides because the referenced national laboratory reports are relevant to SFR designs
- NRC staff determined that models in the computer code and the TR discussion of the use of the code, including parameter selection, reflect the physical and chemical forms of released radionuclides from an SFR design in general
- NRC staff determined that the TR is consistent with the descriptions of source term characterization in RG 1.247, Section C.1.3.16 for MST analysis for non-LWR PRA for use in risk-informed activities, and the general aspects of source term characterization in RG 1.183

Source Term EM Closure Models

- The source term EM modeled radionuclide transport and retention phenomena in the source term EM either by models built into the computer codes used or by user-defined assumptions
- TR section 4.2 includes an overview of the closure relationships and phenomenological models for each of the computer codes used in the source term EM
- Closure models discussed in the TR are pool scrubbing, aerosol radionuclide natural deposition, functional containment modeling strategy, and radionuclide transport

Pool Scrubbing

Sodium pool scrubbing -

- NRC staff determined that the TR methodology, as subject to SE Limitation and Condition 4, appropriately accounts for radionuclide removal through aerosol scrubbing in the subcooled sodium pool

Spent fuel pool water scrubbing -

- NRC staff review determined that the TR methodology assumption is acceptable because it is reasonable and is subject to evaluation in subsequent analyses which implement the TR

Aerosol Radionuclide Natural Deposition

- TR states that aerosol natural deposition is credited in the cover gas region for DBAs
- NRC staff determined use of the Henry's correlation implemented in RADTRAD as a model for aerosol gravitational settling is acceptable
  - Based on aerosol removal experiments using sodium oxide aerosols, which are similar in size distribution to the potential aerosol releases from a sodium pool that can be applied to the anticipated Natrium DBAs
  - RADTRAD implementation of Henry's correlation is conservative because it only accounts for radioactive aerosols in determining the aerosol density within the volume
- NRC staff finds the TR modeling of aerosol transport and retention in the functional containment to be acceptable

Functional Containment Modeling Strategy

- TR section 4.3.3 describes the methodology's interaction with the TerraPower functional containment modeling strategy. It states:

  The strategy directs the development of models to demonstrate the adequacy of the functional containment to perform its primary safety function to mitigate the on-site and off-site dose consequences to the acceptance limits established for the various events. As an integral part of that scope the modeling will include analyses to:

  - *Evaluate compartment environmental conditions (pressure, temperature, humidity) to be assessed against design limits of the compartment structures and barriers (i.e., barriers can reasonably be relied on for a confinement function)*
  - *Determine or confirm pressure temperature dependent compartment leakage values to be used as input into radionuclide transport calculations*
  - *Evaluate compartment conditions from a sodium-chemical reaction.*

Functional Containment Modeling Strategy

- NRC staff determined that the TR methodology strategy for modeling of functional containment is acceptable
  - Provides a structured evaluation of the barriers to radionuclide release for each event
  - Assesses the sensitivity of final dose results to the functional containment modeling assumptions
- NRC staff determined that the selected code that provides event-specific thermal-hydraulic conditions within the functional containment is appropriate because it is consistent with the code purpose
- NRC staff determined that the TR methodology’s handling of potential sodium fires is adequate because it uses a code applicable for sodium fires

Radionuclide Transport

- NRC staff determined that the TR methodology strategy for modeling of radionuclide transport is acceptable because it provides a structured evaluation of the radionuclide release from fuel and models the transport and retention phenomena within the barriers to radionuclide release for each event.
  - NRC staff determined that the radionuclide mitigation phenomena listed in TR section 4.3.4.2 are consistent with the discussion of potential radionuclide transport mechanisms in the non-LWR PRA standard MST analysis element as endorsed by RG 1.247
  - NRC staff confirmed that the TR radionuclide transport and retention models are based on first principles or are empirically derived, are models that are consistent with the technology-inclusive phenomena models used in the NRC-developed version of the RADTRAD code, and use conservatively biased user inputs

Uncertainties in the MST and Transport Phenomena

- NRC staff determined that the methodology accounts for uncertainties in the modeling of source term phenomena by recommending the use of conservative approaches, as justified subject to Limitation and Condition 6
- NRC staff determined that the discussion of uncertainty is consistent with the characteristics and attributes to achieve the objectives of an MST as identified in RG 1.247, Section C.1.3.16

EM Adequacy Assessment

- Element 4 of the EMDAP assesses the adequacy of the EM through bottom-up and top-down evaluations
- The TR indicates that work supporting EMDAP Element 4 is ongoing and that the work will be completed prior to the submittal of an OL application implementing the methodology
- Although the EM adequacy assessment is not complete at this time, the NRC staff determined that the discussion of the ongoing work and future plans, subject to SE Limitation and Condition 5, is sufficient for the methodology development stage given the relevance of the methodology at the construction permit stage

EM Adequacy Decision

- The TR states that TerraPower has not made the source term EM adequacy decision yet
- This work is planned to be complete prior to submission of an operating license application and the information will be provided in a future licensing submittal
- The NRC staff finds that this information is sufficient for the methodology development stage given the relevance of the methodology at the construction permit stage

Limitations and Conditions

1. The methodology is limited to a Natrium design that has a pool-type, SFR design with metal fuel and sodium bond as described in TR sections 1.3 and 2.3.1. Changes from these design features will be identified and justified in Safety Analysis Reports of Natrium license applications.
2. The fuel failure fractions during normal operation and transient conditions are subject to the qualification of Type 1 fuel.
3. If bonded sodium is not utilized in subsequent fuel designs, additional information shall be provided to justify the fission product release behavior from metal fuel to the gas plenum.

Limitations and Conditions

4. The sodium pool scrubbing and associated radionuclide retention within the primary sodium coolant is limited to where the bulk sodium is in subcooled conditions.
5. 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. This verification and validation information should be justified to reasonably bound the operational envelope for the design for any applicant referencing the source term EM methodology.
6. User inputs to analytical tools used in the source term EM (e.g., parameter values) for which specified values are not provided in this TR should be documented and justified in the analysis supporting a license application referencing this TR methodology.

Limitations and Conditions

7. The source term EM described in this methodology results in MSTs intended for use in LMP-based license applications or other best-estimate plus uncertainty analyses. For applications using another process (e.g., conservative deterministic licensing analysis using postulated maximum hypothetical accident), the user must demonstrate that the TR methodology is applicable to that other process.

Limitations and Conditions

8. The TR documents that certain activities related to the development of the source term EM have not been completed. These activities are relevant to Steps 6, 7, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19, and 20 of the EMDAP. This also includes ongoing work related to experimental data to justify the source term phenomena closure models as described in TR section 3. An applicant or licensee referencing the methodology developed in this TR must submit documentation and justify that the identified activities have been completed to a state that is appropriate for the intended licensing application and that the identified information has been provided.

Overall Conclusions

The NRC staff determined that NAT-9392, Revision 0, subject to the limitations and conditions in the SE, provides an acceptable approach for developing MSTs to show compliance with the regulatory requirements for prospective Natrium reactor construction permit or operating license applications under 10 CFR Part 50

Acronyms

- DBA – Design Basis Accident
- DF – Decontamination Factor
- EAB – Exclusion Area Boundary
- EM – Evaluation Model
- EMDAP - Evaluation Model Development and Assessment Process
- EPZ – Emergency Planning Zone
- FOM – Figures of Merit
- LBE – Licensing Basis Event
- LPZ – Low Population Zone
- LWR – Light Water Reactor
- LMP – Licensing Modernization Project
- MST – Mechanistic Source Term
- NEI – Nuclear Energy Institute
- NRC – Nuclear Regulatory Commission
- OL – Operating License
- PIRT – Phenomena Identification and Ranking Table
- PRA – Probabilistic Risk Assessment
- PDC – Principal Design Criteria
- RG – Regulatory Guide
- SE – Safety Evaluation
- SFR – Sodium Fast Reactor
- TEDE – Total Effective Dose Equivalent
- TR – Topical Report