# Official Transcript of Proceedings

# NUCLEAR REGULATORY COMMISSION

## OPEN TRANSCRIPT & SLIDES

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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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NUSCALE SUBCOMMITTEE

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OPEN SESSION

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TUESDAY

MAY 15, 2018

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 1:00 p.m., Walter L. Kirchner, Chairman, presiding.

COMMITTEE MEMBERS:

WALTER L. KIRCHNER, Chairman

RONALD G. BALLINGER, Member

MICHAEL L. CORRADINI, Member

VESNA B. DIMITRIJEVIC, Member

JOSE MARCH-LEUBA, Member

JOY L. REMPE, Member
PETER C. RICCARDELLA, Member
GORDON R. SKILLMAN, Member

ACRS CONSULTANT:
STEPHEN P. SCHULTZ
DESIGNATED FEDERAL OFFICIALS:
ZENA ABDULLAHI
MIKE SNODDERLY
ALSO PRESENT:
BRUCE BAVOL, NRO
MICHAEL BRADBURY, NuScale
ALLYSON CALLAWAY, NuScale
TIMOTHY DRZEWIECKI, NRO
CHRIS KIRBY, NuScale
VICK NAZARETH, NuScale
JENNIE WIKE, NuScale
*Present via telephone

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

P R O C E E D I N G S

12:59 p.m.

CHAIRMAN KIRCHNER: The meeting will now come to order. This is a meeting of the NuScale Subcommittee of the Advisory Committee on Reactor Safeguards. I am Walt Kirchner, Subcommittee Chair today for the review of the two NuScale topical reports, one TR-0616-48793, Nuclear Analysis Codes and Methods Qualification, and two, TR-0116-21012, Revision One, NuScale Power Critical Heat Flux Correlations.

ACRS members in attendance today are Ron Ballinger, Gordon Skillman, Michael Corradini, Pete Riccardella, Jose March-Leuba and Joy Rempe. We also have a former member and consultant, Stephen Schultz, with us today.

Dr. Rempe is conflicted on matters related to Studsvik scanning power that's mainly related to the neutronic methods and therefore will recuse herself from review of the neutronic methods topical report and any associated letter writing.

Zena Abdullahi and Mike Snodderly are the designated federal officials for this meeting.

Today the staff, the NuScale applicant and their consultants will brief us on the content of two topical reports and their applicability to the NuScale design and operating conditions. The staff will establish the basis for their findings on these two reports.

We have one bridge line arranged for interested members of the public to listen in during the open portion of the meeting. In order to minimize noise, this line will kept in mute. At the end of the open portion of the meeting, we will request if anyone listening would like to make further comments.

We have not received written comments or requests for time to make oral statements from members of the public regarding today's meeting.

A separate closed bridge line is available for NRC and applicants and their consultants. And please place your phones on mute to minimize interference. Also state your name, the organization you are representing before we commence the closed portion of the meeting. That's I think, going to be in reference to those who are coming in on the bridge line for the contractor and the staff.

I request all parties to acknowledge and confirm that the participants in the phone conference are members of staff and/or the NuScale applicant and their consultants. And that's obviously relevant to the closed portion of the meeting.

As the meeting is being transcribed, I request that participants use the microphones located throughout this room when addressing the subcommittee. Participants should first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

Let me remind you to please ensure that all electronic devices have been placed in silent mode to minimize disturbances during the meeting.

We will now proceed with the meeting and I call -- oh, pardon me, Vesna Dimitrijevic has also joined us for the record.

MEMBER RICCARDELLA: Walt?

CHAIRMAN KIRCHNER: Yes, sir.

MEMBER RICCARDELLA: I am also conflicted on this topic so I will not participate in the deliberations.

CHAIRMAN KIRCHNER: On both neutronics and CHF? Both topics?

MEMBER RICCARDELLA: I believe so.

CHAIRMAN KIRCHNER: Okay. Okay. Thank you. And now we will proceed. Who is going to be up first? Allyson, are you starting? Or Jennie? Okay. Please.

MEMBER CORRADINI: You need the green light to shine.

CHAIRMAN KIRCHNER: Yes. And pull it closer to you if you can. That will help.

MS. WIKE: I apologize for the brief noise as I'm moving. So my name is Jennie Wike. I am the licensing manager for NuScale's DCA review. So I'll kick off our first presentation.

You know, as Chairman Kirchner mentioned, NuScale is here today to present on two topics. We're going to start out with the topical report on nuclear analysis codes and methodology.

First, we're going to do some introductions of who's presenting on this topic. So, you know, I already introduced myself.

I'm the NuScale licensing manager. My background, I've been with NuScale for roughly four years. Previous to this, I worked at Xcel Energy at the Monticello and Prairie Island Nuclear Generating Plants. And prior to that, I did some R&D work because I graduated from the University of Wisconsin with a materials science degree and did some R&D work before moving into nuclear power.

CHAIRMAN KIRCHNER: Does that conflict our chairman?

MEMBER CORRADINI: No.

CHAIRMAN KIRCHNER: No. Thank you. I just wanted to understand.

MEMBER CORRADINI: She's in the wrong department.

MEMBER REMPE: You'll hear him say it's okay since she didn't go to that department that he's in.

MS. WIKE: But we were right next door, connected by the skyway. All right. Allyson.

MS. CALLAWAY: So my name is Allyson Callaway. I'm the supervisor of the nuclear analysis group and the interim supervisor of the core form hydraulics group.

I've been with NuScale for eight years. Before that, I came from Oregon State University from their nuclear sharing department. Go ahead.

MR. KIRBY: My name is Chris Kirby. I'm a consultant with Structural Integrity Associates. I've been doing work for NuScale for about five years in the nuclear analysis and core design group.

Before that, my experience is with San Onofre Generating Station for about six years during core design and nuclear analysis in a nuclear fuel management group. And before that I worked at Bettis

Atomic Power Laboratory for a year working on the core designs.

And my educational background is a degree in physics and a degree in nuclear engineering from the University of Michigan.

MR. NAZARETH: And I'm Vick Nazareth. I'm the director of nuclear fuel at Structural Integrity Associates. My background is I worked at Combustion Engineering for 10 years. And then I worked at San Onofre for 25 years. I was the last director of nuclear fuel at San Onofre. And unfortunately Harold isn't here or he'd remember that.

So I've worked in the industry for 35 years, all in nuclear fuel, different aspects of nuclear fuel.

MS. CALLAWAY: Okay. So with that we'll get started with the open session for the nuclear analysis codes and methods topical report.

A quick agenda. This is the agenda for the open session. Some of these topics we'll cover in more detail in the closed session.

So we'll go over an overview of the purpose of the topical report and then a high level brief overview of the code system that we're qualifying.

We'll give a review of some of the relevant aspects of the NuScale reactor design. And we'll talk about the overall validation approach and the benchmarking we've done as far as the topical report, generation of our nuclear reliability factors and some of the applications that NuScale is going to use the code for.

So this is just a quick overview of what's in the topical report. So the topical report is seeking approval to use CMS5 code suite from Studsvik for physics design and analysis for the NuScale reactor.

So within the topical report, we've benchmarked this code for NuScale applications and for the NuScale design. With the benchmarking we've developed biases and bias uncertainties and developed nuclear reliability factors out of that which will mostly be referred to as NRFs from here on out by us, I think.

And then the culmination of the topical reports is the validation of the code for physics applications for NuScale.

MEMBER MARCH-LEUBA: Let me ask a question, a different question. I'm asking about 10 CFR Appendix B, particularly when the typical paradigm is for vendors to have their own codes, which they have licensed and approved and they maintain. It's not unusual for Studsvik for be part of that.

But here, who is going to be the holder of the license? Who's in charge? Who is responsible to do Appendix B on those codes?

MS. WIKE: Sure. So NuScale has an approved QAPD topical report. And so we do have a license. Though I say license, just utilizing your words, we just have an approved topical report to implement Appendix B at NuScale for our applications across --

MEMBER MARCH-LEUBA: I'm more interested on the codes themselves. When you're not the final repository for the code, like I know, this student in Nigeria finds a problem with CASMO5 and reports it to Studsvik, how does that change translate into the planned operation?

MS. WIKE: Right. So we would be notified through a Part 21 notification because we would be using that code.

MEMBER MARCH-LEUBA: So you're going to get periodic updates from Studsvik? You'll always be using the latest version or the version that you froze in 2018?

MS. CALLAWAY: We'll be using the dedicated version, the version that we've qualified. And then we would requalify any new version that we'd like to upgrade to.

MEMBER MARCH-LEUBA: So once you qualify the code, it becomes your version of the code even though you didn't change any code. And that's the one that is approved, right?

And then that code derived from a repository somewhere in Studsvik, that somebody found a mistake on that one. And that needs to eventually migrate into your version.

MS. WIKE: Mm-hmm. So what we're seeking approval of in our topical report, and let me know if this better answers your question, we're approving the application of the code to the NuScale analysis.

MEMBER MARCH-LEUBA: But not the code.

MS. WIKE: But not the code itself.

MEMBER MARCH-LEUBA: I'm worried a little bit it's a different problem, but the application of Appendix B to codes that don't belong to me.

MS. CALLAWAY: So in general, if an error is identified, we would either reconcile the error or update to a newer code version where that error has been resolved and then revalidate through our dedication process.

MEMBER MARCH-LEUBA: I want you to say that you will keep the codes up to date not -- or at least you tried to for your mistakes. You have to evaluate it if the change is significant. And if you change it, at which point do you reevaluate?

MS. WIKE: Yes. Our Appendix Bravo Program would require us to evaluate any errors. So if Studsvik found an error in the code and they communicated to that us, usually through a Part 21 notification, then we would evaluate it under Appendix Bravo. And at that point we'd have to, as Allyson mentioned, either resolve it because maybe the error doesn't impact how we're applying the code. But if it does impact what we're doing, certainly we would have to address that.

MEMBER MARCH-LEUBA: Yes. I have one or two reservations that when there's multiple ownership that those things become difficult.

MS. CALLAWAY: Okay. So we'll cover those codes a little bit more in the closed section. This is the initial high level overview of the codes so starting CASMO5, that's a lattice physics code. It's using ENDF/B-VII.1. And it's the 2D transport solver that develops the nuclear data in cross-sections.

The CMSLINK compiles all the cross-sections into a library and that library is the primary input into SIMULATE5. SIMULATE5 uses the diffusion equation in a 3D model basically built up of the cross-sections from the library using 3D core simulation.

So that's the general code flow. CASMO5 and SIMULATE5 are the latest versions of the codes. CASMO4 and SIMULATE3 are fairly prominent in the industry. And so these are the latest versions. Studsvik has just also submitted a generic topical report for us.

MEMBER MARCH-LEUBA: Are you already making commercial use of CASMO5 approved to date in the U.S.?

MS. CALLAWAY: Duke uses CASMO5 currently. I believe they've licensed that themselves. And I think that Dominion is or will be going through an 8311 with Studsvik's general code.

MEMBER MARCH-LEUBA: The way I worded the question is CASMO5 on paper is infinitely superior to CASMO2 for sure, right? The question is we've been tweaking those old codes forever and not in just special factors here and there to make them work.

And now when you work, like, on 5 maybe

those three factors don't apply. So I'm interested to follow-up on benchmarking against reoperating conditions in real plants.

How do they -- better code follows the old plant. And obviously you're not going to have a NuScale core to do that, but you should be plugged in on experiences from Duke or whoever has it or European experience to make sure that you don't make the same mistakes.

DR. DRZEWIECKI: I'm sorry. This is Tim Drzewiecki. I mean, that's something that will be covered in our presentation. There is a generic CMS fact topical report. And there is plenty of operating plant benchmarking that's reflected in that topical report, over 63 plant cycles, I believe.

MEMBER MARCH-LEUBA: Mostly foreign plants?

DR. DRZEWIECKI: No. It's U.S. plants.

MEMBER MARCH-LEUBA: A U.S. plant, yes. Thanks.

MEMBER SKILLMAN: Does Studsvik maintain a user's group for their codes? And I presume if they do, NuScale is a member?

MS. CALLAWAY: Yes.

MEMBER SKILLMAN: For both.

MS. CALLAWAY: Yes to both.

MEMBER SKILLMAN: Both of their codes. Thank you.

MS. CALLAWAY: Okay. With that, I will turn it over to Chris, and he's going to cover some of the more relevant aspects of the NuScale design.

MR. KIRBY: So this slide just presents some general parameters of the NuScale core and fuel design. And as it relates to the codes, modeling of the NuScale core is not much different than modeling typical PWR except for the size and the power level.

As you can see, the core is composed of 37 assemblies with 16 CRAs. The fuel assemblies are standard 17 x 17 design, 24 guide tubes and one instrument tube.

The fuel has a maximum UO2 enrichment of 95 percent, UO2 and its encapsulated M5 cladding. An active fuel length is two meters.

The control routes have a split composition of 37 centimeters of silver indium cadmium at the bottom and that's followed by B4C at the top for the remainder of the rod. And then gadolinia is used as a printable absorber, which is combined homogeneously with the UO2 and fuel pellet.

And one of the features of the NuScale

design, as it relates to safety, is its resiliency to, or stability with respect to xenon oscillations.

So analysis that we've done with SIMULATE has shown when we perturb the core to cause a xenon transient that the xenon oscillations are quickly damped out and the core returns to equilibrium, usually within one oscillatory cycle. So it's different than a big PWR. It's very stable.

MS. CALLAWAY: If I could interrupt quickly, I think you said it was 95 percent max enrichment. You meant --

MR. KIRBY: 4.95 percent, yes. Thank you for that.

MEMBER REMPE: If I could interrupt for a second, just for clarification. When I was looking at this report versus the CHF report, which clearly said a particular fuel type, I didn't see a specific fuel type identified. And somewhere I thought in some of the material we were given there was a time where NuScale didn't have a fuel or they switched from one fuel to another.

And I was just curious, is this topical for the particular fuel type that you are now going with? Or what's the story on the fuel? Is this topical for it?

MS. CALLAWAY: So the generic parameters of the fuel type that apply, whether we are using a prior fuel design or this fuel design, is the general applicability of this topical report. So the 17 x 17.

MEMBER REMPE: So when we write, or when the Committee writes a letter on this, they should not reference the specific fuel type on this topical report. You want it to be more general for more than the AREVA fuel type that you're currently going with. Correct?

MS. CALLAWAY: Yes.

MEMBER REMPE: Okay.

DR. DRZEWIECKI: This is Tim again. This is something which is addressed in the staff's safety evaluation that there is some flexibility in terms of your fuel type, but there's also a limitation provided in the SE in terms of there's only certain materials that are inside of the CMS5 code suite. And so they are limited, obviously, to those.

MEMBER REMPE: Thank you.

MR. KIRBY: So as you can see in this slide, it's a depiction of the heavy reflector around the core. That reflector contains cooling channels to remove the heat generated by the gamma radiation. And the heavy reflector for NuScale was designed to control leakage, improve fuel utilization and evenly distribute power throughout the core.

As can be seen in the figure, the reflector thickness varies around the core and ranges from about 10 centimeters to about 30 centimeter.

Standard reflector modeling in CASMO5 and SIMULATE5 is used to model the reflector, but the number of reflector sections model depending on the reflector geometry.

Modeling multiple reflector segments based upon position around the core and material composition of the various segments was done to maintain the fidelity of the model, keeping the distinct regions of the reflector separate.

The ability of SIMUALTE5 to accurate model the SIMULATE reflector has been demonstrated by our core benchmarking, which we'll go into a little bit later and specifically comparisons to MCNP.

And now we'll go back to talk a little about the validation of the code with Allyson.

MS. CALLAWAY: So we used three different, I guess, primary categories for benchmarking. The first one was code-to-code benchmarking with MCNP, empirical benchmarks of critical configurations and experimental reactors and commercial reactor benchmark to TMI1.

MEMBER MARCH-LEUBA: So you say you're doing a full core MCNP?

MS. CALLAWAY: Yes.

MEMBER MARCH-LEUBA: Full three?

MS. CALLAWAY: Mm-hmm.

MEMBER MARCH-LEUBA: You have plenty of servers to run it on?

MS. CALLAWAY: It takes awhile to run.

MEMBER MARCH-LEUBA: It takes awhile, right?

MS. CALLAWAY: Mm-hmm. So those benchmarks comprise our code validation. And the results of the code validation are used to develop biases and bias uncertainties.

MEMBER MARCH-LEUBA: Just curious, on MCNP model, to what level do you homogenize? You don't model every pin do you?

MS. CALLAWAY: Yes, we do.

MEMBER MARCH-LEUBA: You model every pin on every fuel assembly?

MS. CALLAWAY: Yes.

MEMBER MARCH-LEUBA: I'd love to see that model.

MR. KIRBY: Remember, it's only 37

assemblies.

MEMBER MARCH-LEUBA: Yes. But there is the 17 x 17 pins. I know MCNP allows you to repeat the limits, but, geez, you're talking dissertation for if you bring it out, you get your Ph.D. just out of it.

MS. CALLAWAY: Okay. So the results of the benchmarking we used to develop biases and bias uncertainties are tolerance limits as its given here. And those values we develop nuclear reliability factors to encompass them and the nuclear reliability factors and the validated code are ready for downstream application.

So that's the general process that we followed for validation and the basic flow of the top core part that we're talking about.

Okay. So a little bit more on code to code --

MEMBER REMPE: I have another question on that slide, too. And this is more because, again, of the interface with the thermal hydraulics. NuScale is going to operate at lower pressures and lower flow conditions.

And, again, I'm not an expert what all Studsvik did to validate their codes, but in all of these benchmarks, did they consider a case that would give you appropriate benchmarks that would consider void coefficients and moderate greater coefficients because of the different conditions that you're operating at?

I mean, I know the benchmark of BWR conditions as well as PWR conditions. But did you look and say, oh, yes, this one really will give us the right void coefficient and moderator coefficient?

MS. CALLAWAY: So the closest benchmark that we have for that is the commercial benchmark.

MEMBER REMPE: PMI1?

MS. CALLAWAY: And it's 400 psi, I think, lower pressure, but generally, fairly similar operating conditions. Also, with the code-to-code benchmark with MCNP, you know, pressure doesn't necessarily draft input. But we looked at a number of different densities of the coolant as part of that benchmark. So we get those implicitly in a couple of different ways.

MEMBER REMPE: Because again, when I think about things we've heard so far, ATWS concerns and things like that are more important. And so that's why I'm real curious on that.

MS. CALLAWAY: And so moderator

coefficients would be similar with the benchmarking we looked at.

MR. NAZARETH: And so let me add a little bit more to that. Typically when you do a code like this, am I on or off? Sorry.

Typically when you do a code like this, you benchmark to operating data. That's the key aspect of what it is, but NuScale has no operating data. So the benchmarking done here that's described over here is very extensive to make up for whatever it is you're going to have.

So the MCNP, you have to go into that level of detail because you have to have two codes that match up perfectly to say that the benchmarking was okay. Okay?

And then same thing with the empirical benchmarks with the criticality and so on. Now TMI data is the closest data we could find that will give us the kinds of things we wanted to do for which you're talking about. And so we used that.

And then ultimately we set up, we compared against the industry standards just to see that we're not off, that we're consistent with what the industry standard was for those kinds of item.

And so, these in the end, we added

conservatisms to account for things we didn't know. Okay? We expect to verify that during startup testing in this middle half of this table over here.

When it says update methods, we actually put the methods in and how we validate it after we get actual startup data and make sure it's still conservative. Okay? But we had to do much more extensive benchmarking because of the fact that the NuScale conditions are unique.

MEMBER REMPE: Thank you.

MEMBER SKILLMAN: Let me expand on Dr. Rempe's question, please, Vick.

MR. NAZARETH: Sure.

MEMBER SKILLMAN: The first couple cycles of TMI1 were at 2413, not 2568, four pumps running. Very high Reynolds numbers.

MR. NAZARETH: Yes.

MEMBER SKILLMAN: And an enrichment that's very different than yours.

MR. NAZARETH: That's correct.

MEMBER SKILLMAN: And early, early TMI enrichments were 3.5, 4.1 max. And you're 4.95 with a 24 month fuel cycle. Why is the TMI data applicable?

MR. NAZARETH: So the TMI -- okay. So the

TMI data is applicable to the point of simulating actual operating data. Okay? It could have taken many different things like that. The specific things with enrichment and all of that, we did the code-to-code benchmarking to match that up really well. Okay?

And the TMI data is like the last step to close the ranks to make sure we're actually using an operating data from a plant to match up as well as we can. And then we added some more conservatism to the top of that. Okay?

So we brought in -- there is many -- in the Studsvik generic topical report, they brought up data from many different plants, most of them Dominion plants here today. Okay. So they had a broader based look at all the plants. Okay?

So what we did in the end is we came together with that and said, well, for whatever we don't have -- because you can run infinity with the amount of data that you wanted to. Whatever data we don't have, we'll make certain conservative adjustments to make sure we're not -- we're within the realm of what we expect to be for this particular run. So it's the best we got, really, to match up with as many things as we could.

MEMBER SKILLMAN: Thank you.

MR. KIRBY: Can I clarify something? The two year cycle length doesn't have a blanket 4.95 percent enrichment. That's just the maximum enrichment from the scale. For the two year cycle, the average enrichment is 3-1/2, 4 percent, something right around those numbers. I just wanted to clarify that.

MEMBER MARCH-LEUBA: But do you have gadolinia?

MR. NAZARETH: Yes.

MEMBER MARCH-LEUBA: That's something that broadly the very early TMI code didn't have.

MR. NAZARETH: That's correct.

MEMBER MARCH-LEUBA: That would be the biggest difference.

MR. NAZARETH: And this is why did the code to kill kind of thing, right? Because we needed to be able to duplicate that we could model those kinds of things. This is why we also compared it to the industry data to make sure they were not stepping out of things that are different. But gadolinia is fairly well known now. Framatome uses it all the time so it's not that unusual.

MEMBER MARCH-LEUBA: Going back to my original comment which you probably forgot already is this are you relying on the Studsvik valuation also?

MR. NAZARETH: Okay. So let me add something more to that. Okay? So Studsvik is an independent resupplier. So if there are errors in their code, they're required to tell NuScale about the errors. And then NuScale evaluates that to make sure it complies with NuScale's Appendix B program. Okay?

So for things that are nice to have, NuScale doesn't have to take them in or not. With error reporting, it has to be done and correctly. That is a requirement for an Appendix B supplier. And there is what's called a NUPIC audit that goes back to suppliers of codes and validates them.

MEMBER MARCH-LEUBA: I'm not picking on you.

MR. NAZARETH: No, no, no.

MEMBER MARCH-LEUBA: I'm trying to understand --

MR. NAZARETH: I'm just explaining the system of our -- because many utilities now are doing independent analyses, right? APS is doing their. Duke is doing it. Dominion is doing it. We did it. It's ours.

So the same kind of thing. We take over whatever the vendor codes are. It doesn't have to be a field vendor anymore. Take over the vendor codes. An Appendix B supplier, they're required to provide you with error reporting.

MEMBER MARCH-LEUBA: And then are you required to validate your code independently from the vendor?

MR. NAZARETH: You assess it and you evaluate it independently, correct. You are the licensee. So this gives the responsibility to validate.

MEMBER MARCH-LEUBA: You cannot rely on the validation that the vendor, Studsvik, probably knows more about this than you do.

MR. NAZARETH: No. You do rely on it because they give you all the information relative to that. Right? The impacts and all of that, they do the impact assessment and all of that. Okay?

So you apply it to yourself what is the homogeneric application?

MEMBER MARCH-LEUBA: Well, what gives me a very nice warm feeling is well, we just held there are 65 cores that we have validated, that's validated on their own. You've done one.

MR. NAZARETH: Yes.

MEMBER MARCH-LEUBA: So I don't have 65.

I have one. Let's degrade for it.

MR. NAZARETH: That's why we got all this benchmarking, right? Tons of it because we try to fill in as many gaps as we can.

CHAIRMAN KIRCHNER: Just out of curiosity, has Studsvik used this code suite on boilers, on BWRs?

MR. NAZARETH: They have. The answer to that is yes.

CHAIRMAN KIRCHNER: Okay.

MR. NAZARETH: Which ones, I'm not quite sure. But the answer to that is yes. It's generically --

CHAIRMAN KIRCHNER: So that I would guess they would have benchmarked. And therefore, they would have data at 1000 psi and different flow conditions than typical of the PWR. So it may provide some confidence that the code scale through a range of pressures and flows and associated neutronic parameters that are typical.

It's almost as if, without making any judgment, it's like the NuScale design is somewhere between a BWR and a PWR with your natural circulation and your lower pressure. And I guess we'll hear more about that when we get to critical heat flux.

But if Studsvik has benchmarked against

boilers, that's enhanced competence that the code scales through substantially different thermodynamic and neutronic conditions.

MR. NAZARETH: Yes. That's interesting.

CHAIRMAN KIRCHNER: Okay.

MS. CALLAWAY: Okay. So just a bit more detail on the code-to-code benchmarking to start. As we have said, the code-to-code benchmarking is CMS5 compared to MCNP6. And the benefit here is that we're comparing two different methods of deterministic versus a stochastic method of very detailed MCNP6 model.

Because it's a code-to-code benchmark, we're not relying on a fixed number of data points. We have flexibility in the number of data points that are available to us. So most of the physics parameters that are important to us for the validation we have the ability to benchmark through this method.

We can move on to the next slide unless anybody has any questions on that one. So the empirical benchmarking, the commercial reactor is included in this but we did do a large amount of critical experiments and experimental reactor benchmarking as part of our empirical benchmarking as well.

And the empirical benchmarking and the commercial reactor benchmarking gives us real data to compare against a limited number of data points and still a substantial amount, we have actual measured data that we start to get to compare to.

MEMBER MARCH-LEUBA: What I don't see on that slide is core depletion. I mean, it feels like you consider it more to a particular space, the operating condition, and calculated it to power distribution. Did you do the core depletion to match the K effect as a function of time?

MS. CALLAWAY: Yes, yes. We get that out of the TMI benchmark.

MEMBER MARCH-LEUBA: That's the TMI?

MS. CALLAWAY: Mm-hmm. Yes. So there's two cycles of core deletion.

MEMBER MARCH-LEUBA: That's much harder to do than a single point.

MS. CALLAWAY: Yes. And so commercial data benchmarking, we've covered this quite a bit already. So TMI, you know, on cycles 1 and 2 are modeled. We get all of our key physics parameters benchmarked through this commercial reactor comparison.

So the commercial benchmarking, the other empirical benchmarking, the code-to-code benchmarking, as a recap, we use the results of those in combination with developed biases and bias uncertainties and use those to develop NRFs for NuScale's application of the code.

And then the final recap of the process. I guess, I mostly just said all of this. So once the NRFs are developed, we use those for the initial NuScale design. And as soon as we're starting up, we have the ability to validate those NRFs and then start collecting additional data to either confirm or update the NRFs once we have NuScale's specific data available to us.

MEMBER MARCH-LEUBA: And these are penalties when they are effective? Give me, like, an example of an NRF.

MR. NAZARETH: Can we talk about that more in the closed session? Because we're actually presenting some of those things there.

MS. CALLAWAY: I can give you an example for now would be a penalty to use your words on control out growth.

CHAIRMAN KIRCHNER: And so since we're in open session, I think it's useful for the record and the public to just compare your NRFs that you generated with utility. Could you highlight that? Are they bounded by typical values used by utilities? You have a table on Page 78 of your report, industry standard values.

MS. CALLAWAY: Yes. So that's --

MR. NAZARETH: Yes, so.

CHAIRMAN KIRCHNER: That's public information. Can you just go qualitatively, just say how your NRFs compare with industry benchmarks or standards?

MR. NAZARETH: Okay. Our NRFs are more conservative than the industry benchmarks then. Okay? So the specific details we will provide in the closed session.

CHAIRMAN KIRCHNER: Sure.

MR. NAZARETH: But in general, that middle bullet that says as conservative factors, they're set up to be conservative relative to all the types of benchmarking that we did, okay, at a 95/95 probability confidence level.

And we'll talk about -- we have some of the statistics in the topical report for anything else you want to see. But they are more conservative than in the industry.

CHAIRMAN KIRCHNER: And so going into

startup testing, you're using more conservative nuclear reliability factors than are typical in the industry?

MR. NAZARETH: Yes.

CHAIRMAN KIRCHNER: That's what I wanted you to say.

MR. NAZARETH: Yes. There is one parameter that is more conservative, and I'll have to explain it.

CHAIRMAN KIRCHNER: Okay.

MR. NAZARETH: In the closed session. Okay?

CHAIRMAN KIRCHNER: All right. Thank you.

MS. CALLAWAY: Okay. I'll let Chris take over the last couple of slides for this session on the code application.

MR. KIRBY: Okay. So NuScale was planning to use the CMS5 to perform core designs and to provide input to safety analysis. And in doing so when they performed these calculations, they will be applying NRFs to the CMS5 results in order to ensure a conservative result on the analysis.

They also would like to use CMS5 to perform startup physics testing and also do core follow-up predictions. And in using the code in this manner, that would also help to validate the NRFs that have already been established and provide data to update their NRFs when an enough data has been presented.

So in summary, NuScale has performed extensive benchmarking into the CMS5's code suite for application to the NuScale design. The benchmarking process has resulted in the development of nuclear reliability factors for use in the application of the code system to perform nuclear analysis. And these NRFs will be validated and updated when operating data from NuScale modules becomes available.

MS. CALLAWAY: That is the end of our open session of material for nuclear analysis, codes and methods topical report.

CONSULTANT SCHULTZ: Allyson, I have a general question. And it has to do with NuScale support of the overall application and basically who did what?

MEMBER MARCH-LEUBA: Steve, can you put the green light? Oh, you have? Sorry.

CONSULTANT SCHULTZ: Oh, it's on. And the question is, have you some consultants in your -- as I understand it in your application, you relied upon Studsvik methodology. I don't know how much Studsvik participated in this particular application. What I'm most interested in is going forward.

NuScale is going to have a staff that's going to move this in to the next phase of the licensing process. And I wanted to get an appreciation for what NuScale is doing to make sure that the staffing that they have is well-experienced in doing that application.

It has certainly benefitted from consultants in developing the licensing application. But going forward, you might leave those consultants behind and have a group that's going to make this satisfactorily move forward. And where are you now and where are you going?

MS. CALLAWAY: Okay. So Studsvik didn't participate at all in the development of this work short of obviously supplying the software. But the rest of the validation work and the contents of the topical report and the rest of the work that supports what's in the topical report.

CONSULTANT SCHULTZ: But you must have consulted with them to at least develop an understanding that what you were doing was an appropriate application of the code?

MS. CALLAWAY: Yes, yes. So they do

provide training on the code, yes.

CONSULTANT SCHULTZ: Good.

MS. CALLAWAY: But otherwise the use and application of it is then independently owned as a function by NuScale. Does that fully answer your question?

CONSULTANT SCHULTZ: And that included the development and submittal of the application and the RAI responses and so forth?

MS. CALLAWAY: Yes.

CONSULTANT SCHULTZ: Okay.

MS. CALLAWAY: Yes. So it will be NuScale's staff or augmented staff. But the work and the process and the technology and ownership of the actual property is also --

CONSULTANT SCHULTZ: Augmented staff, and is that augmentation going to continue or is it envisioned to be more of an in-house activity?

MS. CALLAWAY: The scope of the topical report was for approval for NuScale Power to apply these methods. And certainly we do intend to be a design center for our future plants. And dependent on how many plants we have --

CONSULTANT SCHULTZ: Understood.

MS. CALLAWAY: -- that will determine our staffing. But certainly we would hope to have hundreds. If there's any potential customers --

CONSULTANT SCHULTZ: Thank you. That clarifies my concern and your consideration. Thank you.

CHAIRMAN KIRCHNER: Okay. Why don't we continue with the CHF correlation presentation.

MS. WIKE: All right. So we're moving on to the next NuScale open presentation on the critical heat flux correlation topical report. So we do have a new presenter joining us at the table. So I'll have Mike introduce himself, give a little bit of a short bio before we roll straight into the PowerPoint slides.

MR. BRADBURY: Okay. Good afternoon. My name is Mike Bradbury. I'm staff aug to NuScale from ISL. And I was the lead of the CHF correlation development.

With some of my prior experience, I worked on mPower mostly thermal hydraulics stuff. I worked at AREVA for six or seven years with PPR and such things. And then --

CHAIRMAN KIRCHNER: Michael? Can I interrupt and ask you just pull your microphone a little closer and speak out a little more?

MR. BRADBURY: Okay.

CHAIRMAN KIRCHNER: Please.

MR. BRADBURY: And then prior to AREVA, I worked at Cappell for six or seven years as well. So I think that's me.

All right. So for the agenda, I'll just do a quick overview of what the CHF topical is, some introduction background information, the overview of the development of the NSP1, 2 and 4 correlations and then a little bit of a discussion about VIPRE and our use of it.

Okay. So the overview, essentially NuScale was seeking NRC approval to use both, or either, the NSP2 or NSP4 CHF correlations in safety analysis. The CHF testing that we have was performed -- we had actually two kind of rounds of testing.

The first was done at Stern Labs and then we have additional from the Framatome's KATHY facility in Germany. And VIPRE was used in the correlation development and is also used as the analysis tool for safety analysis.

So this slide, we'll just kind of get into a little bit what makes, you know, NuScale special. The NuScale SMR operated under some unique conditions, most notably the low flow from natural circulation since we don't have forced flow pumps.

MEMBER CORRADINI: So maybe this is in closed session. So you tell me to stop. Where do you measure the flow in the design? We can wait.

MR. BRADBURY: In the design --

MEMBER CORRADINI: In other words in actual operation.

MR. BRADBURY: In actual operation, I would have to get back to you. I'm not sure exactly.

MS. WIKE: Yes. Let us get back to you in the closed session.

MR. BRADBURY: So, you know, we needed a NuScale specific CHF correlation basically because our flow rates are very low. You know, the PWR, the typical test in flow rates go down to about 1/2 million pounds per hour foot squared. And we need data below that.

So that's, you know, we went off and tested our -- at those conditions, which isn't necessarily easy. CHF testing at low flows can be kind of tricky.

We also have a shorter heated length, which does play a little into the testing. You know, ours is about a 6-1/2 feet length bundle versus 12 or 14 for conventional PWR.

So, like I said, we ran two different campaigns. The first was at Stern and that was back in 2012, 2013. And then we did a prototypical NuFuel-HTP2 bundled design test at KATHY in 2016.

MEMBER REMPE: So, I know Stern and KATHY have now been used quite a bit in various applications. But I still am interested in how you have confidence in the calibration of the sensors. And I know the report said you had diverse means.

And I guess I'm curious if you know of any cases where they found that a sensor went bad and they replaced it. Because, you know, if you have two sensors and one is reading different from the other, you don't know which one is right. And so I'm curious about that.

Is there a potential that they both could have drifted? And I know there's something in the report that even said, well, all we care about is the difference in temperature. And, again, if things are drifting, I don't have a lot of confidence in the difference in temperature or flow or whatever the parameters you're measuring.

And so can you give us any of your insights about why you are comfortable and confident of the calibration of the sensors?

MR. BRADBURY: I'm not aware that any sensors failed during our test campaign. I don't --

MEMBER REMPE: In the past, when you talked to them, before you gave them money to do the test, did you ask them about those kind of questions?

MR. BRADBURY: I believe, yes. And we came away with confidence that they would be able to adequately test. I can't speak too much to the Stern data in that regard because that was before my time. But at least with KATHY testing we, you know, discussed those things and --

MEMBER REMPE: And what gave you confidence that they were taking care of it?

MS. WIKE: Do you mind if I jump in?

MR. BRADBURY: Oh, absolutely.

MS. WIKE: So we do have, like I mentioned, an approved Appendix B Program. And we did do a QA audit of the testing facilities to ensure that their controls and how they were running the facilities met our Appendix B expectations for quality.

MEMBER REMPE: But I just am curious in just knowledge of what they did -- and I don't know what Appendix B folks who were auditing would do to give them that confidence. But what do you do? I mean, I ran tests at a laboratory. And I know some of the things we did and I just am curious in what they did and why you felt comfortable.

MR. BRADBURY: Yes. I'm not sure that I'm the right person to answer that.

MEMBER REMPE: If you have time, maybe there's time to get back to us. I'm just curious if you could write a couple paragraphs and let us know.

MR. BRADBURY: Absolutely.

MEMBER REMPE: Thank you.

MS. WIKE: Okay. Next slide.

MR. BRADBURY: Sure. All right. So a little background on the NuFuel-HTP2 design itself. We covered this a little bit in the nuclear analysis code of methods. You know, it's a conventional 17 x 17 arrayed fuel bundle. Like I said earlier, it's shorter than normal for typical PWRs.

We are using Framatome's HTP and HMP spacer grids. And those have been used extensively throughout the industry, both in B&W-type plants and Westinghouse type plants. So there's quite a history with those.

MEMBER SKILLMAN: Could you please go back? Were the tests that were conducted tests that were conducted at the Stern and KATHY tests that used an assembly that looked like this?

MR. BRADBURY: The one at Stern --

MEMBER SKILLMAN: Let me say it different.

MR. BRADBURY: Sure.

MEMBER SKILLMAN: An assembly that was assembled like this.

MR. BRADBURY: The one at Stern was not because that was prior to us having Framatome as a fuel vendor. So the one at Stern, you know, while the lattice was the same, you know, the pitch and the diameters and broads and stuff that are the same, the grids were just simple non-mixing space requirements. So they would not represent this product.

Now what was tested at the KATHY facility was this actual product with the correct spans and, you know, like, for instance, the bottom, you know, grid before even the heated length, HNP, and then there's HTPs and there's an HMP at the top. I mean, down to the that, you know, they put all the right spacer grids in all the right places for the KATHY test.

MEMBER SKILLMAN: So I hear you say for the KATHY test it is virtually an identical --

MR. BRADBURY: Yes.

MEMBER SKILLMAN: -- device?

MR. BRADBURY: Yes.

MEMBER SKILLMAN: Thank you.

MR. BRADBURY: Okay.

CHAIRMAN KIRCHNER: I think we're -- I'm just scanning your slides, I don't think you are showing us in your slide deck that's for the open part the actual test array. It that 5 x 5 or?

MR. BRADBURY: Yes. It is a 5 x 5.

CHAIRMAN KIRCHNER: All right.

MR. BRADBURY: Which is pretty standard for --

CHAIRMAN KIRCHNER: Okay.

MR. BRADBURY: All right. So a little background on the operating conditions. When we compared it to traditional PWRs, NuScale relies on a much lower flow, obviously due to the lack of poor circulation. And commensurate with that we also have a much lower power density for linear heat generation rate, whichever way you'd like to look at that.

So, you know, in this plot you can sort of see NuScale as an outlier away from the other PWR plants.

Now one of the things we look at is Power-to-Flow just to see, you know, it kind of gives you an indicator on how aggressively you're going to be pushing the thermo-hydraulics.

And NuScale's is a little higher than, you know, other designs like EPR, AP1000. But when you compare it to the typical Westinghouse Plant for the AP1000, it's not drastically higher. So, you know, that gives us confidence that we're not pushing it so hard that we're going to, you know, be pushing ourselves into a constant CHF problem.

CHAIRMAN KIRCHNER: In addition to linear heat rate, what about typical heat fluxes?

MR. BRADBURY: The average heat flux is -- I want to say it's very low. I'm not sure of an exact number.

MEMBER CORRADINI: We can get to it in the closed session.

MR. BRADBURY: Yes, that's fine. I mean, we can talk about it there.

MS. WIKE: Okay.

MR. BRADBURY: Sure. All right. Okay. So it's a little convoluted how we got to our CHF correlations due to what we were talking about earlier with having -- you know, the Stern test doesn't model exactly, you know, what we're planning on putting in, et cetera.

So our initial correlation was this NSP1 correlation. And that was built off of the Stern data that we had gotten back in 2013.

Like I said it had a generic non-mixing spacer grid, but it was -- the testing was very expansive in terms of conditions, like very low relative to where the NuScale reactor is fairly high, you know, mass fluxes. Pressure range was very large, covering almost, you know, way below where a BWR would go to until, you know, up to where a PWR would normally be tested, things like that.

So it was a very thorough database, but, you know, it just wasn't the final design. So we used that to develop this NSP1 correlation. And then in early 2015, we changed fuel vendors to Framatome. And we were going with this NuFuel-HTP2 design, which then had the HTP and HMP grids and that.

And so what we did was to make sure that, you know, the correlation we would have would work with that. We were able to obtain a limited amount of data from AREVA that was relevant.

And we could look at that with this NSP1 correlation and we did. And it wasn't -- the correlation didn't do a great job of predicting it partly because it wasn't tuned to predict that.

So we developed this NSPX factor which it was intentionally designed to have conservatism. It addressed the trend difference that we saw with that small set of data from Framatome. And it also added an intentional, you know, like 5 percent extra conservatism. Because the way we were working at the time, we were going to have to be using the correlation while we were in parallel getting the data for the actual bundled design.

So we built in a little bit of risk mitigation by adding conservatism. And then once we actually received the data for the NuFuel-HTP2 design in 2016, we used that set of data to validate the combination of NSP1 and NSPX, which is what we refer to as NSP2.

MEMBER CORRADINI: So what is NSP4?

MR. BRADBURY: I will get to that, I believe, on the next slide.

MEMBER CORRADINI: Oh, sorry.

MR. BRADBURY: Oh, no, that's fine.

MEMBER SKILLMAN: Okay. Just before we change slides, NuFuel-HTP2 trademark.

MR. BRADBURY: Yes.

MEMBER SKILLMAN: If you will codify it such that it is married to the NuScale design forever and ever?

MR. BRADBURY: Okay. So when you say that, do you mean, would Framatome use it another plant or do you mean it (simultaneous speaking)?

MEMBER SKILLMAN: For any NuScale plant must the new NuScale plant use only NuFuel-HTP2 TM?

MR. BRADBURY: If they are -- if their safety analysis is performed with either the NSP2 or the NSP4 correlation, than yes. Now, if we switched fuel vendors 20 years from now --

MEMBER SKILLMAN: A whole new package.

MR. BRADBURY: Right. We'd have to --

MEMBER SKILLMAN: Re-analysis.

MR. BRADBURY: Right. We'd have to get a whole new correlation and such, yes.

MEMBER SKILLMAN: Okay. So what we're really talking about here is this 37 fuel assembly plant with 16 control rods up to 4.95 percent enrichment using NuFuel-HTP2 TM.

MR. BRADBURY: For the CHF correlation, yes. As far as -- I'll let you jump in on the other.

MEMBER SKILLMAN: The analogy in my mind is when you buy a vehicle from a vehicle manufacturer, you get an engine, probably designed and built by that manufacturer for that vehicle. You don't get a different engine.

And so what I'm coupling in my mind is, okay, I got it. I understand what they're doing. But for the suite of analyses and for the effort that is going into this, the buyer of the first NuScale design uses this fuel and only this fuel unless there's a re-analysis for fuel?

MS. WIKE: Correct.

MR. BRADBURY: Correct.

MEMBER SKILLMAN: It seems crazy, but I'm just trying to get it set in my mind. Thank you.

CHAIRMAN KIRCHNER: Let me ask a different question. NSPX is that a constant or a variable correction?

MR. BRADBURY: It's a variable.

CHAIRMAN KIRCHNER: Like a Tong factor, then?

MR. BRADBURY: Kind of.

CHAIRMAN KIRCHNER: Has it any physical bases?

MR. BRADBURY: Yes. In developing it, I think we'll get a little more into this in the close. But in developing we, you know, looked at sensitivities to various -- you know, I mean, in the main frame there's a pressure, flow, et cetera, et cetera. So, you know, we analyzed those things to see, okay, you know, what seems to have the most trend here? And then we picked the one that it seemed to have the most trend with and used that.

And we designed it so it's conservative. Like, we added the conservatism in. We designed it so that you'll never get a benefit from it. So it's only ever the worst -- or at best it's a penalty. You won't ever gain from it, I guess.

CHAIRMAN KIRCHNER: Now stop me if I get into something closed, but normally, in the industry, the history is the spacer grid designs have been used to enhance heat transfer.

And typically that gives you the ability to run the fuel at a higher heat flux and still have a significant margin in your margin to either, in your case critical heat flux or DNB in the larger PWRs. So I'm trying to just understand your language here.

You were saying repeatedly that the NSPX factor conservatively extends the NSP1 correlation.

MR. BRADBURY: Right. Okay. So to make it a little clearer.

CHAIRMAN KIRCHNER: Because the reason I'm struggling with the verbiage here is that NSP1 was developed with, you know, the plain vanilla non-mixing grid. Once you go to your actual fuel with its nice mixing veins and all of that in the grids, then one expects better performance thermo-hydraulically speaking.

MR. BRADBURY: I can discuss that. I think that probably needs to be in the closed session.

CHAIRMAN KIRCHNER: Okay. I'll wait.

MR. BRADBURY: I'm ready to discuss it but -- okay. I'll take a note and I'll bring it up at --

MS. WIKE: Okay. NSP4.

MR. BRADBURY: All right. The NSP4 correlation. So NSP2, if you look at it, we developed it based on the Stern data really and a small subset of data from Framatome. And then we validated it with the NuFuel-HTP2 data. Okay. That's a non-traditional of doing it. Normally, you would --

MEMBER CORRADINI: But when you say validate, based on how you describe NSPX multiplying NSP1 getting NSP2.

MR. BRADBURY: Mm-hmm.

MEMBER CORRADINI: It should, if I had a 45 degree line, always underpredict or predict CHF before you actually saw it experimentally.

MR. BRADBURY: Correct.

MEMBER CORRADINI: Okay.

MR. BRADBURY: Yes. So the NSP2 was more

of a convoluted way of getting there. And that was just due to scheduling essentially. NSP4 was a clean slate. You know, we developed it off of the NuFuel-HTP2 specific CHF data.

We validated it with the same data. It's more the normal process you would expect to go through for developing a CHF correlation. So that's what the NSP4 correlation is.

And what that gets us is it turned out the NSP2 was very conservative. So NSP4 helps regain some of those margins for other things, you know, whether it is to do something that, you know, where you have to accommodate a higher heat flux or, you know, whatever could come up.

MEMBER CORRADINI: But let me ask a different question. And, again, I'm not sure what you showed on a slide somewhere, some box somewhere, about flow versus power.

MR. BRADBURY: Oh, yes.

MEMBER CORRADINI: The design point didn't change or did it?

MR. BRADBURY: No. The design point does not.

MEMBER CORRADINI: So essentially, you've regained margin to be used or to be known, but not to be changing the design that you --

MR. BRADBURY: Correct.

MEMBER CORRADINI: -- now submitted.

MR. BRADBURY: Correct. Right. We would not change anything with the DCI or anything like that.

MEMBER CORRADINI: Okay. Fine. Thank you.

MR. BRADBURY: So basically, you know, the process for NSP2 was kind of convoluted. You started with one set of data. You validated with a different set of data. And then the process for NSP4 was more traditional where, you know, you created the correlation to the actual data you care about and validated it as such. Okay.

CHAIRMAN KIRCHNER: But, again, it might explain, I think, gets to what I was thinking that your terminology -- you have a static design. But your finding improved with your -- not improved data. With more data that's more prototypical of your design, your margins are greater with the static design.

MR. BRADBURY: Right. Given the particular design, we'll call it the NSP2 correlation --

CHAIRMAN KIRCHNER: Yes.

MR. BRADBURY: -- because that's what I've been calling it. That one predicts very conservatively. Like, you know, if you pop up the CHF data and you've got that 45 degree line, like, all of it will be below it.

CHAIRMAN KIRCHNER: Yes.

MR. BRADBURY: And it's just very, very conservative. And that's fine. I mean, you know, in the Rev 0 or whatever of the DCA, that's what we used and, you know, we were able to survive, you know, transient scenarios. You know, but the desire was there to, you know, recover margin in case things come up in the future or, you know.

CHAIRMAN KIRCHNER: In case you have spare change in your pocket and you want to come back for an upgrade.

MR. BRADBURY: Maybe. Something. There's lots of options where certainly margin never hurts you so that's --

MEMBER CORRADINI: But I think just so we're clear, you quantified the margin. You didn't change the design.

MR. BRADBURY: We did not change anything in the design.

MS. WIKE: That's correct.

MEMBER MARCH-LEUBA: The thing I don't really understand on this little bit higher level is why are you asking approval for NSP2 if NSP4 works just as well and is much better than NSP2? Why are you wasting our time?

MR. BRADBURY: We'll let Jennie.

MS. WIKE: Yes. Well, the answer is we had originally submitted the topical report with NSP2.

MEMBER MARCH-LEUBA: So you worked very hard on it so you're making us work hard on it?

MS. WIKE: We didn't want to restart the review. There was a lot of overlap in our correlation development between NSP2 and NSP4. And we wanted to use that and so we added NSP4 to this existing topical. And that's why we kept NSP2.

MEMBER MARCH-LEUBA: It was supplemental rather than (simultaneous speaking).

MS. WIKE: Correct. When you see us again for the applicable chapters in the DCA, you'll see that we use, like for example, in Chapter 14, NSP4. So while this topical covers both NSP2 and NSP4, in our DCA we've adopted NSP4. Next slide.

MR. BRADBURY: All right. So both of these correlations, NSP2 and NSP4, are implemented in

VIPRE. You know, VIPRE is a pretty ubiquitous Subchannel T/H code. It's used by numerous vendors and utilities. It has the generic SER.

And we did, you know, do all the use case stuff. I'm not going to talk about it here because that was in a separate topical report. That was in Subchannel Analysis Methodology Topical Report.

But the point is that, you know, we took the generic SER. We do show that it is applicable for NuScale. And then, you know, one of the key things here is, you know, all of the constituent of models and such that you would pick for using an analysis are identical to what was used in the CHF development.

So the CHF correlation itself is acting as a closure model, kind of tying the application back to testing.

MEMBER MARCH-LEUBA: So, yes, honestly, I'm not picking on you. I'm just trying to learn. Is EPRI an Appendix B supplier for you?

MR. BRADBURY: EPRI is not the -- the code is owned at this point by Zachary.

MEMBER MARCH-LEUBA: And they are an Appendix B supplier?

MR. BRADBURY: Yes.

MEMBER MARCH-LEUBA: Okay.

MEMBER REMPE: Well, if they're going to be overlapped, we're going to do a separate review on using VIPRE for NuScale and, I assume, each of the documents references certain of each other's document.

MR. BRADBURY: Pretty much.

MEMBER REMPE: And if there's something you6 find wrong in here, you'll have to update the VIPRE document and vice versa. And that's the plan. You'll just do a rev.

MR. BRADBURY: Yes. They are pretty inexplicably tied.

MEMBER REMPE: Yes.

MEMBER CORRADINI: So just for my memory, did Zachary used to be Nuclear Numerical Applications?

MR. BRADBURY: Well, yes, that was --

MEMBER CORRADINI: They're renamed.

MR. BRADBURY: That wasn't the -- who was it? CSI, that's right.

MEMBER CORRADINI: Okay, fine.

MR. BRADBURY: Yes. Computer Simulation something, I think.

MEMBER CORRADINI: Thank you.

MR. BRADBURY: Okay. So effectively we have two CHF correlations with the NSP2 and the NSP4 that we developed. We feel they're both applicable to

NuScale. The NSP2 is conservative, which was good in some ways. And the NSP4, you know, we can regain margins.

You know, the topical report provides the test data, provides the details of the correlation development, provides the limits for the correlations, which tie back to GDC10. And it also gives the applicability range and criteria. And that's what we're seeking approval of.

CHAIRMAN KIRCHNER: Okay. Any questions at this point? Okay. Let's take a brief pause here in situ and have the staff come up and present their evaluation in open session. Go ahead, please.

MR. BAVOL: Okay. Thank you and good afternoon. My name is Bruce Bavol. I'm a project manager for the NuScale project. These are two of my topical reports that we're reviewing. Currently, we completed our review on.

And to my right is Tim Drzewiecki. And I just wanted to let you know that per our agenda that in a closed session, we are going to cover each topic separately to add continuity to the closed material.

The other contributors, Becky Karas is here. She's a branch chief of the Reactor Systems. Jeff Schmidt, who is not. And then we had some additional support for both the nuclear analysis and CHF by Boyce Travis, Josh Kaizer and David Heeszel.

The timeline for the codes and the methods qualification, this particular topical report, as was discussed, came in on August 30, 2016. We had an RAI-8807 came in on May 9, 2017. We got a response back from NuScale. That response was reviewed and closed resolved.

Our future plans are to have an ACRS full committee scheduled currently at June 7. It's a Thursday morning. And we plan to issue a -- our plan is to issue a final SER late 2018. And then publish our approved version early October.

With that, I'm going to turn it over to Tim.

DR. DRZEWIECKI: Thanks, Bruce. So in terms of the findings made for the nuclear codes and methods topical report we're not making findings, of course, on any of the GDCs at this point. Those are made during a DCA review.

But where this methodology is used once approved, it will form a partial basis for those findings.

What was asked for is staff to first approve the application of the CMS5 code suite for the new scale core design as well as the base NRFs which are the numbers that are used to account for the uncertainty in the prediction of those parameters as well as an NRF update methodology.

Key areas of the staff review, and this is kind of how the SE is laid out. One is basically modeling capabilities of the CMS5 code suite, in particular can you mode the appropriate geometry, the material? And do you have the appropriate physics modeling capabilities in this code to do the job?

The assessment of the CMS5 code suite, and that includes the code-to-code comparisons as well as comparisons to any kind of benchmarks and operating data, the NRF update methodology and development, that's mostly a math problem.

And then the last one was the uncertainty of management during operation. And this is even if you have confidence in your NRFs and your update methodology, what if you're still wrong whether you do that? So that was something that we had fleshed out as part of the SE.

Okay. So the areas in which, you know, staff had spent some more time and which you would not do in a traditional review, one as far as the geometry of this plant the fact that you have several modules that are close together, we wanted to ensure that there was no kind of feedback from module to module, especially given the location of the ex-core detectors.

The physics modeling, we wanted to make sure thermo-hydraulic modeling capabilities inside of SIMULATE5 were appropriate. And this goes into things, you know, like your void feedback. Make sure that you can actually capture, you know, your void fraction inside of SIMULATE5.

A validation of analysis, we made sure that, you know, some of the key components here that were different from a plant or the fact that it's a smaller core, higher leakage and it's got a heavy reflector. So we made sure that they had validation data that can address those aspects of this design.

Things staff had considered as part of this review was not only the information provided in this topical and obtained in the REI process as well as the audit of the supporting calculations, but we also looked at the review of the generic CMS5 report as well as the manuals and information that was supporting that review.

Also, we had looked at similar types of reviews that were done in this area, like Duke Power design methodology on any APS reactor physics methodology.

So as far as staff conclusions, on this SER we did find the CMS5 code suite can model the NuScale core design subject to one limitation. And that was that there was a list of materials used in the core design that were fleshed out in the CMS5 generic review. And they are going to be limited to those same limitations here obviously.

But other than that, they are not particularly wedded to a design that would have, like, an M5 cladding. If that were to change in the future, they would not be bound by this topical to use M5. The base NRFs --

CHAIRMAN KIRCHNER: May I interrupt you, Tim, just on the public record, limitation to materials. Now, if I recall, CMS5 is using ENDF/VII, whatever mod.

DR. DRZEWIECKI: That's right, yes.

CHAIRMAN KIRCHNER: So I would assume that's all encompassing of the materials that are being modeled or are there other materials in this design that that cross-section database doesn't cover?

DR. DRZEWIECKI: So it's not limited by the cross-section so much as the closure of equations that are being used to model some of the materials inside of SIMULATE5. Because SIMULATE5 does account for things like fuel burn-up and change in the thermal conductivity. It accounts for things like changes in geometry from swelling. And those have an impact on reactivity. And because of those equations, is why --

CHAIRMAN KIRCHNER: So it's more in reference to the SIMULATE5 --

DR. DRZEWIECKI: Yes.

CHAIRMAN KIRCHNER: -- not the basic neutronics. Thank you.

DR. DRZEWIECKI: Sure. Okay. The second, which is the base of NRF's proposed are acceptable. And going back to one question that was stated before, the base NRFs all account for more uncertainty than the generic CMS5 NRFs.

And last is that the NRF update methodology that was proposed in its topical report are acceptable subject to one limitation and the condition.

And one limitation was that any kind of updates to of a delayed neutronic parameter cannot reduce its magnitude at below 5 percent. And that's based on the data that we had seen. It was kind of limited to that. So we couldn't see -- I mean we could get it lower than that.

And the one condition is that any updates to the peaking factors, they must account for the pin-to-box bias and fixed in-core detector bias in accordance with the generic CMS5 topical report.

CONSULTANT SCHULTZ: Tim, that condition is there because more information needs to come in during operation in order for the overall evaluation to be complete in these areas?

DR. DRZEWIECKI: You mean as far as this condition for the peaking factors?

CONSULTANT SCHULTZ: Yes. This is provided because there wasn't sufficient information based upon lack of operation of the NuScale 4.

DR. DRZEWIECKI: No. It has to do with how these factors were generated in the generic methodology in the sense that when you come up with a pin-to-box bias, that has two factors in there.

One is a comparison of CASMO5 to MCNP6 -- I'm sorry, actually, no. One of the benchmarking of the CASMO5 code to data to basically see how that code actually compares against data and the other was a SIMULATE5 to CASMO5 to look at the uncertainty that you impose for your pin power reconstruction algorithm. Those are fixed values that you really can't reduce by getting more data. And those were set by the code vendor. And so we are requiring that those be maintained.

MEMBER CORRADINI: Oh, I got you. It's the bias that you're maintaining.

DR. DRZEWIECKI: That's right.

MEMBER CORRADINI: As whatever new data will move the performance, you want to maintain the bias, if I understood the condition.

DR. DRZEWIECKI: That's right. That's right. Yes. And there's also a bias associated with having a fixed core instrumentation system, which affects your 3D power peaking factor.

CONSULTANT SCHULTZ: All right. So in spite of what might be developed in the future by NuScale, the obligation is to meet condition one?

DR. DRZEWIECKI: That's right.

CONSULTANT SCHULTZ: Thank you.

MR. BAVOL: Okay. We're going move on to the critical heat flux, the staff reviewed time line. This particular topical report Rev 0 was updated to Revision 1. The revised submittal implements the additional NSP4 critical heat flux correlation and incorporates changes associated with the RAIs that this staff had submitted to point.

There were two key RAIs. RAI-8795 and RAI-8931. ML numbers are provided. Those two are as responded to, completed, resolved and satisfactorily. The staff plans to also have an advisory committee represent the safeguards at full committee June 7, same time. We'd like to have an issue of a final SER late July 2018 and publish the approved version of the topical report also in October 2018.

DR. DRZEWIECKI: So similar to the last topical report, we are not making findings against specific GDCs here and approve the CHF topical report can be used to establish a partial basis, which is used in review of the DCA to make findings against things like GDC10, 12 as well as any kind of omnivaluation of accidents looking at those consequence of analyses.

NuScale had requested this review go through and approve the use of NSP2 and NSP4, the CHF correlations for the safety analysis of NuScale power module with NuFuel-HTP2 fuel over a specified range of applications and with specific CHFR limits.

Key areas of staff review, of course, was data collection, CHF model generation and a large focus of this review was on quantification of the CHF model error, which is how you come up with your CHFR limits.

Areas in which the staff spent more time was on the development of a 95/95 CHFR limits as well as we did look closer at the correlation of behavior because its trends was somewhat different from what we had seen in the traditional PWR. And so we wanted to make sure that we understood why we were seeing that, or at least, you know, know that there was enough data to back up those trends.

I think the staff had considered obviously the information in this topical as well as the RAI responses in the audit of the supporting calculations.

There was an inspection done at Stern Laboratories for 2013 when we were collecting data. There was also a program, a report, that was submitted to the staff in 2014, preapplication space, that pretty much had laid out what their program was going to look like, where they expect in terms of what kind of flow rates and pressures they expect to see in their transient and accident analyses as well as there was an audit done of a KATHY facility in 2016. And then, of course, the information that was obtained from previously reviewed CHF correlations.

And as part of this SE, there was an appendix that kind of lays out the review framework that was informed by several of the past CHF reviews.

MEMBER REMPE: So I'll ask you the same question I asked the applicant about the data and when instrumentation goes bad and what you've seen in the past with your reviews of Stern data and KATHY data. Again, you know, have they had some errors where they detected it? And how was that detected and how was it replaced, the censors replaced and how were they qualified?

DR. DRZEWIECKI: So I have not seen issues with them seeing failures in their, you know, in their calibrated instrumentation.

Something that does give us confidence is both at Stern and at KATHY, they do repeat test points to ensure that they can get, you know, the same points over and over again. Now the way it's done at Stern and KATHY are different. And that's fleshed out some in the closed session. I can explain how that's done at both facilities.

MEMBER REMPE: Okay.

DR. DRZEWIECKI: And so if they fell out of calibration, there are certain reference points where they should be able to go back and check and see that they're still getting the results.

MEMBER REMPE: I'd be interested. Thank

you.

DR. DRZEWIECKI: Okay. So the staff of SER conclusions is that the NSP2-CHF correlation is acceptable for use in performing the safety analysis of NuScale power module with NuFuel-HTP2 fuel with a limit of 1.17 over a range of applicability provided in the table, in that topical report, subject to two limitations.

Similarly, the NSP4 correlation is also acceptable for use with a limit of 1.12 over a range of applicability, which are provided in the topical as well.

Those two limitations are that the non-uniform flux factors, or your Tong factors, have to always be greater than or equal to one. Basically, it has to always be -- it can't be a credit to CHF margin. It's always applied as a penalty.

And that the use of these correlations have to be used in accordance with the Subchannel of Analysis Methodology to be used in accordance with the validation of these CHF correlations.

MEMBER CORRADINI: Which is a separate topical we'll see.

DR. DRZEWIECKI: Yes. That's right. Acceptable topical we'll see.

MEMBER CORRADINI: So, I mean, that makes sense. I'm just trying to find out how this is linked. So how can one agree to use the CHF correlation until we see the subchannel analysis. They seem inextricably linked.

DR. DRZEWIECKI: Well, they are linked. The important thing is that the models used for all of the data reduction calculations are frozen. That's the important thing.

That's what we want to do is to ensure that those models and those code options are frozen which is, you know, that's what's laid out in that subchannel analysis methodology. And so, basically, when you do any kind of subchannel calculation, you know, you have confidence that you're going to get the same kind of -- yes.

MEMBER CORRADINI: And then the next question is so, as I understand the limitation, if used with an approved subchannel analysis methodology, NuScale can apply either to or for?

DR. DRZEWIECKI: That's right.

MEMBER CORRADINI: Okay.

MR. BAZOL: And that concludes our open part of the presentation.

CHAIRMAN KIRCHNER: Okay. Any questions

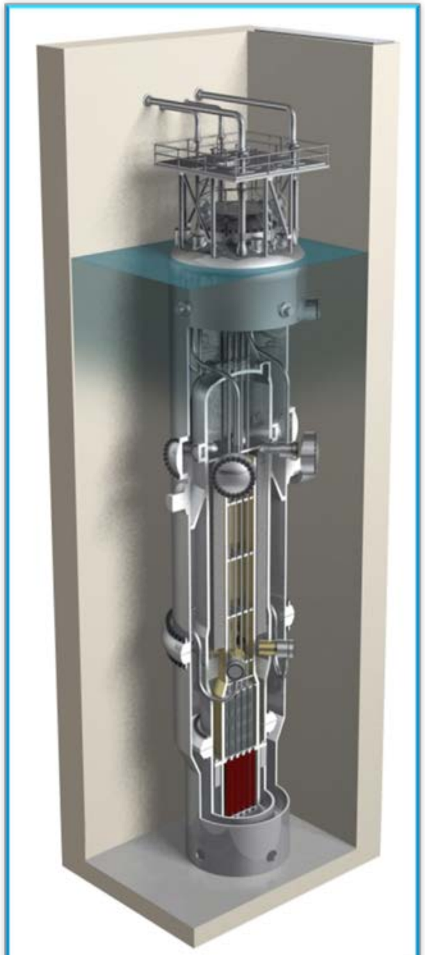
from the members at this point? Let us then turn to any comments from the public and see if there are any members of the public that wish to make a comment? I'm not seeing any present.

Can we -- yes, I know. We'll wait for the bridge line to be opened and see if any members of the public are out there. If there are any members of the public listening in, and if you wish to make a comment, please identify yourself and make that comment. Hearing none, we can close the bridge line, please.

And with that, I propose that we take a break at this point. I assume that we'll have comments from the committee and our consultant after the closed session. So with that we are recessed. Let's come back at quarter of on that clock.

(Whereupon, the open session of the matter went off the record at 2:31 p.m.)

# Nuclear Analysis Codes and Methods Qualification TR-0616-48793 ACRS Presentation



## OPEN SLIDES

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*ACRS Open Session – May 15, 2018*

# Acknowledgement & Disclaimer

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# Agenda

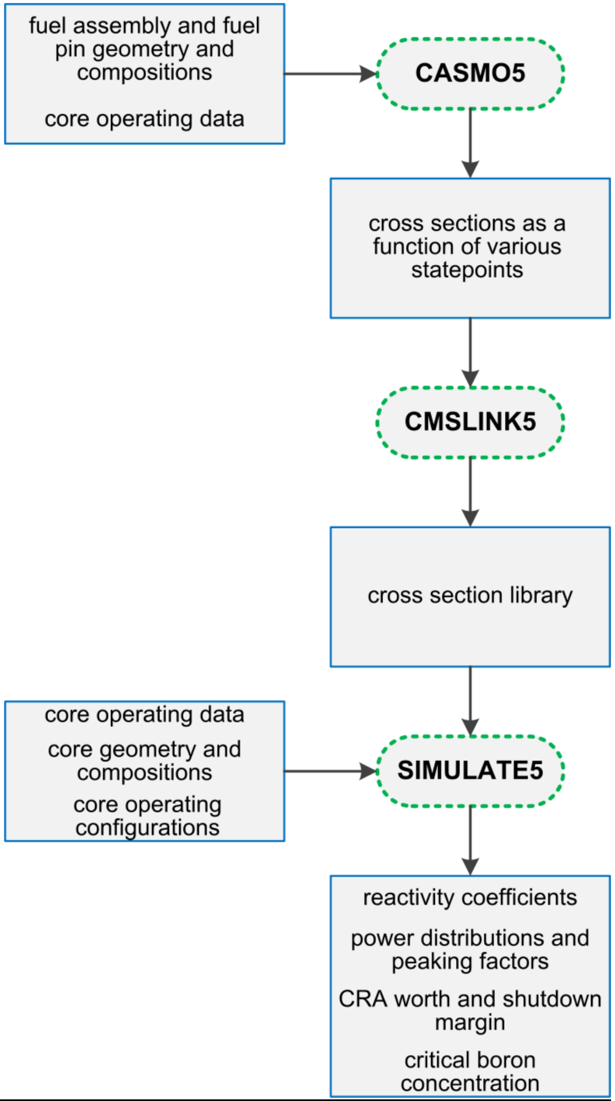
- Overview
- Code Description
- Core and Reflector Description
- Code Validation
- Nuclear Reliability Factor Generation
- Applications
- Summary

# Overview

- NuScale seeks NRC approval to use Studsvik Scandpower's Core Management Software (CMS5) code suite for the nuclear physics design and analysis of the NuScale reactor
- Code suite has been benchmarked for NuScale application
- Nuclear reliability factors (NRFs) have been generated to ensure conservative application for downstream calculations
- Codes have been validated to generate nuclear physics parameters for use in core design, safety analysis, startup testing, and operations support

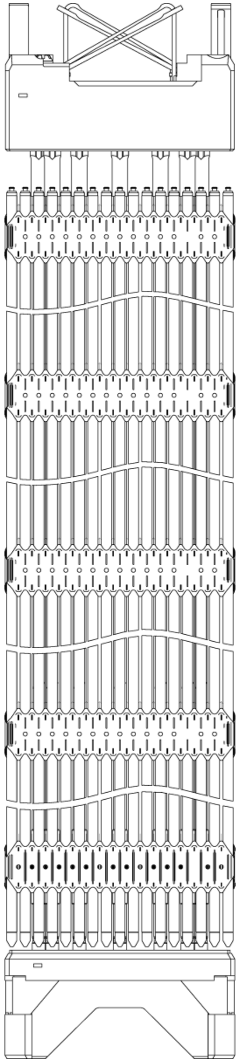
# Code Description

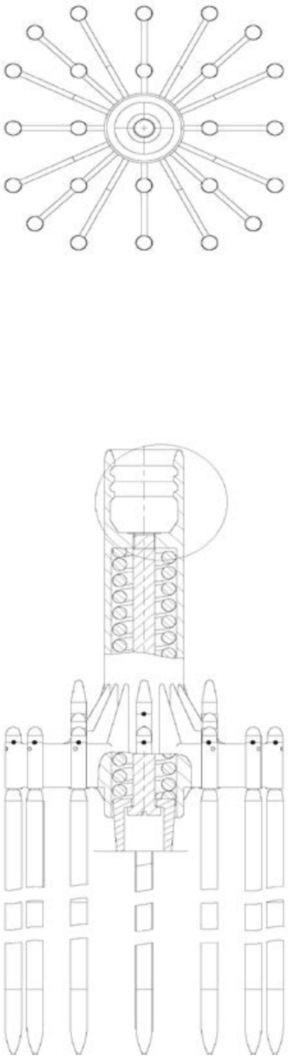
- CMS5 code suite includes:
  - CASMO5
    - Lattice physics code (ENDF/B-VII.1)
    - Uses multi-group 2D/3D neutron transport
  - SIMULATE5
    - Core simulator
    - Uses 3D steady-state, multi-group, nodal diffusion theory
  - CASMO5/SIMULATE5 is the latest Studsvik neutronics code suite version
    - Earlier and latest versions of this code suite are widely used in the nuclear industry for core physics calculations



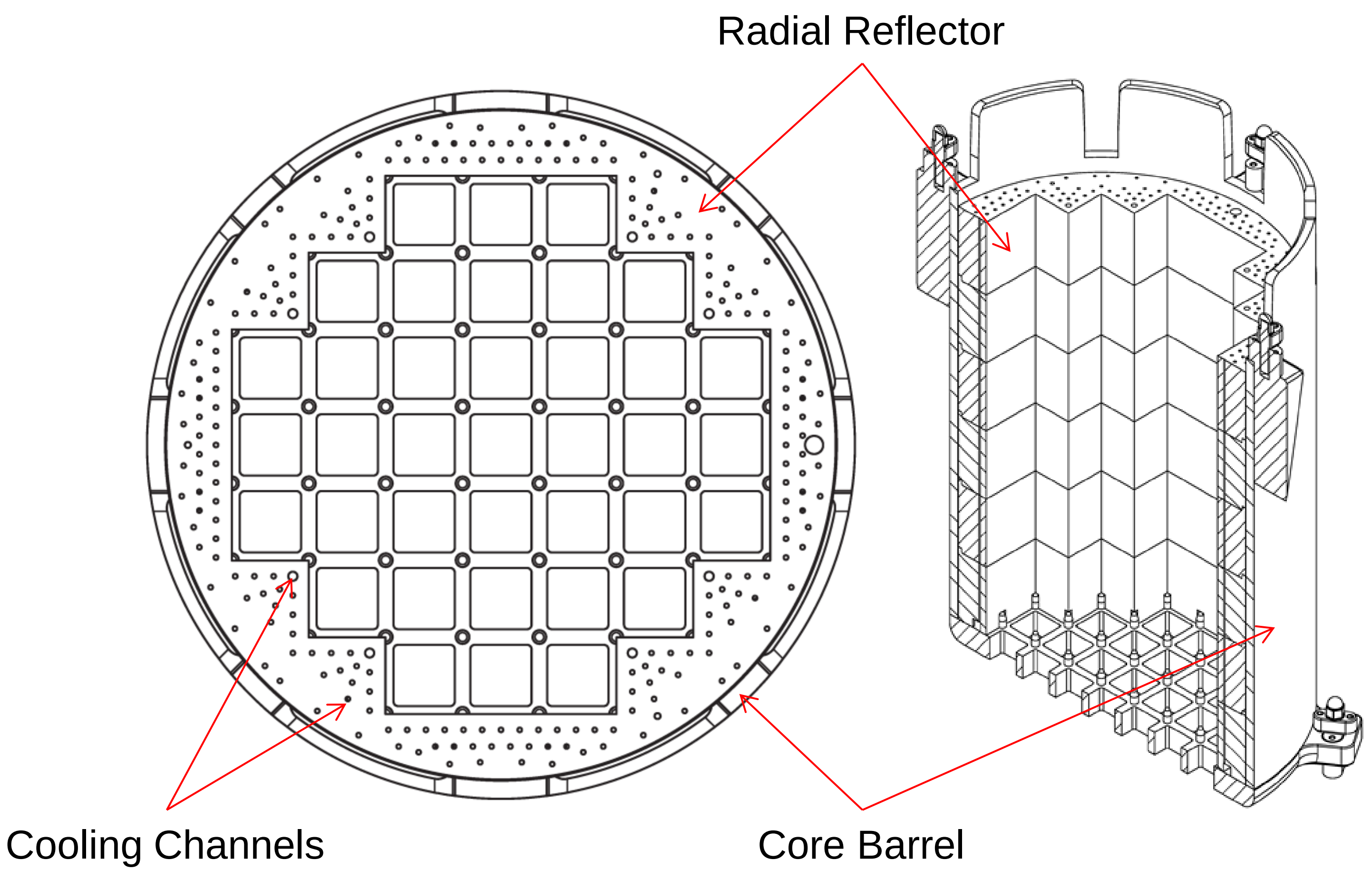
# Core, Fuel, & CRA Description

| | |
|---|---|
| **Core Description** | |
| Power Level, MWt | 160 |
| Number of Fuel Assemblies | 37 |
| Number of Control Rod Assemblies | 16 |
| **Fuel Assembly Description** | |
| Fuel Rod Array | 17x17 |
| Number of Guide Tubes | 24 |
| Number of Instrument Tubes | 1 |
| **Fuel Rod Description** | |
| Material | $UO_2$ |
| Maximum Enrichment, wt% | 4.95 |
| Clad Material | M5® |
| Active Fuel Length, in. (cm) | 78.74 (200) |
| **Control Rod Assembly Description** | |
| Clad Material | Stainless Steel |
| Poison Material | AIC, $B_4C$ |
| **Integral Burnable Poison Description** | |
| Absorber Material | $Gd_2O_3$ |

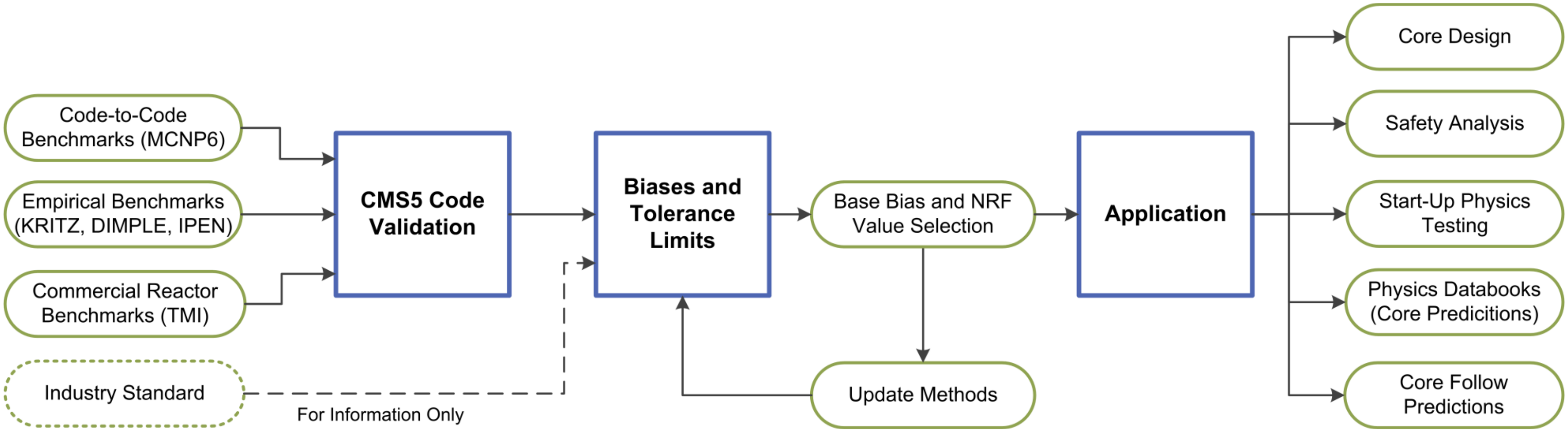




# Core Radial Reflector



# CMS5 Validation Flow Chart



# Code-to-Code Benchmarking

- CMS5 code-to-code comparisons are performed with MCNP6
  - MCNP is considered a higher-fidelity code
  - MCNP6 model is both detailed and specific to NuScale design
  - Parameters benchmarked with this process include $k_{eff}$, peaking factors, power distribution, critical boron concentration, reactivity coefficients, and control rod worth
  - Data from code-to-code comparisons consists of tens to hundreds of data points for each parameter being examined
  - Data points represent either an absolute or relative difference between CMS and MCNP

# Empirical Benchmarking

- Empirical benchmarking by code simulation of criticality data and comparing it to data results
- Types of Data
  - Critical Experiment Data
  - Experimental Reactor Data
  - Commercial Reactor Critical Data
- Parameters benchmarked with this process include $k_{eff}$, power distribution, critical boron concentration, reactivity coefficients, and control rod worth

# Commercial Data Benchmarking

- Commercial Data Benchmarking
  - Use available and relevant operating data to demonstrate ability to accurately predict neutronics parameters with CMS5, as no NuScale-specific operating data exists
- TMI-1 Cycles 1 & 2 were modeled with CMS5 suite
  - Comparisons were made between actual operating data and CMS5 predictions
  - Important neutronics parameters were compared to derive biases and uncertainties
- Results from commercial data benchmarks, empirical benchmarks, and higher-fidelity code comparisons are used to determine bias and bias uncertainties, and in turn develop NRFs for NuScale applications of CMS5

# Reliability Factor Generation

- The benchmarking data discussed previously was used to determine bias and bias uncertainties
- Develop a set of conservative factors called Nuclear Reliability Factors (NRFs) for initial use in the NuScale design
- NRFs will be validated and updated during the startup testing process and module operation

# CMS5 Application

- CMS5 is used to perform core physics calculations for multiple applications in the NuScale modules:
  - Designing and optimizing the nuclear core for initial core and reloads
  - Providing input parameters for design basis safety analysis
  - Generation of startup physics testing predictions
  - Generation of core follow predictions
  - Developing plant physics data books

# Summary

- NuScale has demonstrated acceptability of Studsvik's CMS5 code suite for the nuclear design and analysis of the NuScale design.
- Code qualification is supported by benchmarking against critical experiments, experimental reactors, commercial reactor data, and a higher-fidelity code.
- Qualification has resulted in the determination of conservative NRFs for use in the NuScale analyses.
- Physics parameters generated using this code suite will be used in core design, safety analysis, startup testing, core follow and operations.

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# Presentation to the ACRS Subcommittee

## Staff Review of NuScale Topical Reports

TR-0616-48793, REV 0,
"NUCLEAR ANALYSIS CODES AND METHODS QUALIFICATION"
&
TR-0116-21012, REV 1
"NUSCALE POWER CRITICAL HEAT FLUX CORRELATIONS"

**OPEN SLIDES**

Presenters:


Bruce Bavol - Project Manager, Office of New Reactors
Timothy Drzewiecki, Ph.D.- Reactor Systems Engineer, Office of New Reactors


May 15, 2018

(Open Session)

# NRC Technical Review Areas/Contributors

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  Boyce Travis, NRO/DSRA/SCVB

- Additional Support on CHF:

  Joshua Kaizer, NRR/DSS/SNPB

  David Heeszel, NRO/DSEA/RGS

# Staff Review Timeline

**TR-0616-48793, “Nuclear Analysis Codes and Methods Qualification”**

- NuScale submitted its Topical Report (TR) TR-0616-48793, “Nuclear Analysis Codes and Methods Qualification”, on August 30, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16243A517), as supplemented by letter dated July 6, 2017 (ADAMS Accession No. ML17187B240).
- Staff issued request for additional information (RAI 8807) on May 9, 2017
- NuScale responded to RAI 8807 on July 6, 2017 (ADAMS Accession No. ML17187B239)
- Staff plans to brief advisory committee on reactor safeguards (ACRS) full committee on June 7, 2018
- Staff plans to issue its final SER in late July 2018
- Staff plans to publish the “-A” (approved) version of the TR in early October 2018



Non-Proprietary

# Scope of the Staff Review

- Regulatory Basis
  - An approved nuclear analysis methodology is used to establish a partial basis for compliance with several general design criteria (GDC) of 10 CFR 50, Appendix A
- Applicant requested approval of:
  1. Applicability of Studsvik Scandpower, Inc. (Studsvik), Core Management Software, Version 5 suite (CMS5) to the NuScale reactor core design (RXC)
  2. Base nuclear reliability factors (NRFs)
  3. NRF update methodology
- Key areas of NRC staff review:
  - Geometric, Material, and Physics modeling capabilities of CMS5 (applicability to NuScale RXC)
  - Assessment of CMS5 suite (code-to-code and **empirical data**)
  - NRF development and update methodology
  - Uncertainty management during operation

# Scope of the Staff Review (cont)

- Areas requiring additional review (due to unique design features)
  - Geometry Modeling: Multi-module effects and modeling of heavy reflector
  - Physics Modeling: Thermal-hydraulic modeling capabilities in SIMULATE5
  - Validation analyses to address high leakage cores and heavy reflectors

- Information considered by NRC staff:
  - TR-0616-48793, "Nuclear Analysis Codes and Methods Qualification," and supporting information obtained via RAIs and audit of supporting calculations
  - Documentation provided by Studsvik in support of generic CMS5 topical report:
    - SSP-14/P01-028-TR-NP, "Generic Application of Studsvik Scandpower Core Management System to Pressurized Water Reactors" (ML15355A285)
    - CASMO5, SIMULATE5, CMSLINK5 manuals
  - Similar topical reports/safety evaluations (Duke Power Company Nuclear Design Methodology, Arizona Public Service Company PWR Reactor Physics Methodology)

# Staff SER Conclusions

1. CMS5 code suite is applicable to the NuScale RXC design, subject to Limitation 1:
   – Limitation 1: Application of TR-0616-48793 is limited to the materials identified in the safety evaluation for the generic CMS5 methodology
2. The base NRFs proposed in TR-0616-48793 are acceptable
3. The NRF update methodology proposed in TR-0616-48793 is acceptable, subject to Limitation 2 and Condition 1
   – Limitation 2: Updates to any delayed neutron parameter NRF cannot reduce the magnitude of the NRF below 5 percent
   – Condition 1: Updates to the pin peaking NRFs ($F_{\Delta H}$ and $F_Q$) must include the pin-to-box bias and fixed in-core detector bias in accordance with the generic CMS5 topical report.

# Staff Review Timeline

**TR-0116-21012, Revision 1, “Critical Heat Flux Correlations”**

- NuScale submitted its Topical Report (TR) TR-0116-21012, Revision 1, “Critical Heat Flux Correlations,” on November 30, 2017 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17335A089), this revision replaced the submittal dated October 5, 2016 (ADAMS Accession No. ML16279A363), “NuScale Power Critical Heat Flux Correlation NSP2.”
  - The revised submittal implements an additional NSP4 critical heat flux (CHF) correlation and incorporates changes associated with NRC requests for additional information (RAIs).
- Staff issued two requests for additional information (RAI 8795 on May 8, 2017 - ADAMS Accession No. ML17128A468) and (RAI 8931 on August 21, 2017 - ADAMS Accession No. ML17233A127)
- NuScale responded to RAI 8795 on (July 7, 2017 - ADAMS Accession No. ML17188A461) and RAI 8931 on (September 25, 2017 - ADAMS Accession No. ML17268A385)
- Staff plans to brief advisory committee on reactor safeguards (ACRS) full committee on June 7, 2018
- Staff plans to issue its final SER in late July 2018
- Staff plans to publish the “-A” (approved) version of the TR in early October 2018

# Scope of the Staff Review

- Regulatory Basis
  - An approved critical heat flux (CHF) correlation is used to establish a partial basis for compliance with several regulations including the general design criteria (GDC) of 10 CFR 50, Appendix A:
    - GDC 10 and GDC 12 (margin to fuel design limits), 10 CFR 52.47(a)(2)(iv) and GDC 19 (radiological consequences)
- Applicant requested approval of:
  - Use of NSP2 and NPS4 CHF correlations for the safety analysis of the NuScale Power Module
    - NuFuel-HTP2$^{TM}$ fuel
    - Over a specified range of applicability
    - With specified CHF ratio (CHFR) limits
- Key areas of NRC staff review:
  - Collection of experimental data
  - CHF model generation
  - Quantification of CHF model error (development of CHFR limits)

# Scope of the Staff Review (cont)

- Areas requiring additional review
  - Statistical Analysis – Development of the 95/95 CHFR limits
  - Correlation behavior differs from trends observed in previously reviewed CHF correlations for pressurized water reactors

- Information considered by NRC staff:
  - TR-0116-21012, Revision 1, “NuScale Power Critical Heat Flux Correlations,” and supporting information obtained via RAIs and audit of supporting calculations
  - Inspection report for CHF testing at Stern Laboratories, April 18, 2013
  - NuScale CHF test program technical report, January 24, 2014
  - Audit report for CHF testing at KATHY, August 12, 2016
  - Information obtained from previously reviewed CHF correlations as documented in Appendix A of the staff’s SE

# Staff SER Conclusions

- NSP2 CHF correlation is acceptable for use in performing safety analyses of the NPM with NuFuel-HTP™ fuel
  - With a CHFR limit of 1.17
  - Over the range of applicability provided in Table 8-2 of TR-0116-21012, Rev. 1
  - Subject to Limitation 1 and Limitation 2
- NSP4 CHF correlation is acceptable for use in performing safety analyses of the NPM with NuFuel-HTP™ fuel
  - With a CHFR limit of 1.21
  - Over the range of applicability provided in Table 8-4 of TR-0116-21012, Rev. 1
  - Subject to Limitation 1 and Limitation 2
- Limitations
  - Limitation 1: Nonuniform flux factors must always be greater than or equal to 1
  - Limitation 2: CHF analyses using the NSP2 and NSP4 correlations must be performed in accordance with TR-0915-17564, “Subchannel Analysis Methodology”

# Questions/comments from members of the public before the closed session starts?