Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	Advisory Committee on Reactor Safeguards
Docket Number:	(n/a)
Location:	Rockville, Maryland
Date:	Thursday, October 3, 2019

Work Order No.: NRC-0619 Pages 1-77

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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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667TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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THURSDAY

OCTOBER 3, 2019

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ROCKVILLE, MARYLAND

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2D10, 11545 Rockville Pike, at 8:30 a.m., Peter Riccardella, Chairman, presiding.

COMMITTEE MEMBERS:

PETER RICCARDELLA, Chairman

DENNIS BLEY, Member

CHARLES H. BROWN, JR. Member

WALTER L. KIRCHNER, Member

JOSE MARCH-LEUBA, Member

DAVID PETTI, Member

JOY L. REMPE, Member

DESIGNATED FEDERAL OFFICIAL:

DEREK WIDMAYER

ALSO PRESENT:

STEPHEN M. BAJOREK, RES

JAMES CORSON, RES

AMY CUBBAGE, NRO

HOSSEIN ESMAILI, RES

RICHARD LEE, RES

BOYCE TRAVIS, NRO

KIM WEBBER, RES

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

P R O C E E D I N G S

(8:30 a.m.)

CHAIRMAN RICCARDELLA: The meeting will come to order. This is the second day of the 667th meeting of the Advisory Committee on reactive safeguards. I am Pete Riccardella, Chair of the ACRS.

The ACRS was established by the Atomic Energy Act and is governed by the Federal Advisory Committee Act or FACA. The ACRS section of the USNRC public website provides information about the history of the ACRS and provides factor-related documents such as our charter, bylaws, Federal Register Notices for meetings, letter reports, and transcripts of all full and subcommittee meetings, including all slides presented at the meetings.

The committee provides its advice on safety matters to the Commission through its publically available letter reports. The Federal Register Notice announcing this meeting was published on September 18th. And provided an agenda and instructions and for interested parties to provide written documents or request opportunities to address the committee as required by FACA. In accordance with FACA, there is a designated federal official for today's meeting. The DFO for this meeting is Mr.

Derek Widmayer.

During today's meeting, the committee will consider the following: Advanced Reactor Computer Codes and NuScale certification, application, safety evaluation, and also we have ACRS retreat topics scheduled for today as well. And finally preparation of ACRS reports. As reflected in the agenda, portions of the sessions of both of these topics may be closed in order to discuss and protect information designated as sensitive or proprietary. There's a phone bridge line. To preclude interruption of the meeting, the phone will be placed in a listen only mode during presentations and committee discussions.

We have received no written comments or requests to make oral statement from members of the public regarding today's session. There will be an opportunity for public comment as we've set aside ten minutes in the agenda for comments from members of the public attending or listening in on our meeting. Written comments may be forwarded to Mr. Derek Widmayer, the designated federal official. A transcript of the open portions of the meeting is being kept. And it's requested that the speakers use one of the microphones, identify themselves, and speak with sufficient clarity. I would also ask everyone to silence their cell phones so we don't have interruption of the meeting.

And the first topic is Advanced Reactor Computer Codes. And I will turn the meeting over to our Subcommittee Chairman, Dennis Bley.

MEMBER BLEY: Thank you, Mr. Chairman. This is a culmination of a series of meetings we've had. A while back, we had two meetings -- with -- subcommittee meeting where we learned about the codes that they're developing. And we've had two meetings with the staff on Strategy 2, which is deciding what computer codes they're going to use and how they're going to use them. They've given us Volumes 1, 2, and 3 as an introduction. And there's two more volumes we're going to see at some point later in time. But today we're going to hear about the first three volumes. And then we're going to write a letter on this one. I'm going to turn it over now to Steve Bajorek.

MR. BAJOREK: Thank you very much and good morning, everyone. My name is Steve Bajorek and I'm joined here this morning with James Corson and Hossein Esmaili. And our goal today is to brief the committee on the work we've been doing for Advanced Reactor Computer Codes.

As Dennis pointed out, our topic is referred to often as Strategy 2 of the Implementation Action Plan. The IAP as we call it was started roughly two years ago by the NRC staff in order to prepare ourselves for non-light water reactors. We realized at the time that we were largely a water centric organization. And we had to do a number of different things in order to prepare ourselves for the reviews, which are imminent on us.

Strategy 2 involves development, identification of computer codes, and the tools that we're going to use if needed to do an independent evaluation and analysis of the advanced non-light water reactors. They key word for what we're doing right now and the main objective is that of readiness and preparation. We have been looking at all of the different designs. And our goal is to make sure that the staff has a set of tools that we'll be able to use during the review of any of these types of designs. Right now, our mission is to try to develop these tools to accommodate all of the various plant designs. And I'll show you a figure on how this has been changing.

We consider all of these as equally likely to come in for a design certification. Although we do see a couple of frontrunners right now that we do think will come in very early. This is still about mile three of the marathon. And others may eventually catch up and pass those up.

The licensing approach may or may not use the Licensing Modernization Plan. So when we're developing these codes, we're trying to keep a broad view in that the licensing strategy that these applicants may pursue may use LMP or they may come in with a more deterministic type of approach.

Schedule is very important to us. We have been informed that there are some applicants that may come in for design certification or some type of review as early as this December. And others may be following in --

MEMBER MARCH-LEUBA: Sorry, 2019?

MR. BAJOREK: 2019, yes.

MEMBER MARCH-LEUBA: In two months?

MR. BAJOREK: Yes, two months. That remains to be seen whether they stay to that schedule. But every indication that it will be -- it will be fairly near term. And there's others that are looking at 2020 and 2021, which is still fairly short.

The other aspect in terms of preparedness is that we expect an expedited review schedule. We hope that these plants have large margins of safety. We've seen from previous reviews of advanced light water reactors that there's a large demand from both the applicants and the commission that, that review schedule be much, much shorter than it has been in the past. That means for us when we're developing these tools that sometimes take several years to develop and become acquainted with, get used to, we have to begin a lot of that work well in advance of the actual application.

A lot of the designs are currently under development and what we refer to as the landscape continues to evolve. Some of the designs --

MEMBER REMPE: Steve, before you leave that slide --

MR. BAJOREK: Sure.

MEMBER REMPE: I didn't want to interrupt you, but if you'll go back. Earlier a couple of weeks ago, we had a discussion about activities going on in the Agency with improving Part 50 and 52. And during that discussion, Member Ray brought up, he said do you guys ever try really to encourage some of these folks that Part 50 is really a better way to go when you don't know what you're doing with the design? And not to be rude to these people, but the first time, there are going to be changes. And I know if you don't have insight, it's hard to do Part 50.

(Off mic comment.)

MEMBER REMPE: But it really is -- I mean even with some of our certified design, when changes are made, it's expensive.

MS. CUBBAGE: So this is Amy Cubbage, NRO staff. Way outside the scope of this meeting. That said, in all of our interactions with developers, we inform them on all the available options. And we do advise on pros and cons. Ultimately it's their decision of which path they want to pursue. But I agree with you, there's certain attractiveness to Part 50 for new technologies. Anyway, sorry.

MR. BAJOREK: Okay. No, it's a good point. And as we look at the designs, some are relatively mature. We have a pretty good idea of what the design is going to be, it's power level. Some of the designs are not far removed from cocktail napkins. They're still working on that. And we expect those to change and mature in the years coming.

This shows what we call the advanced reactor landscape. If you haven't seen this for several months, you'll notice it's changing. We're seeing more emphasis on what we're terming "microreactors." The ones that have talked to us so far are cooled by heat pipes. There are others out there that may use some type of a gas as a coolant. So there's diversity in designs in there.

The point to be made on this, we have a variety of coolants. We have neutron spectrums that go from thermal, epithermal, to FAST. Fuels can be TRISO. It might even be an oxide type of fuel that's still under consideration of a couple. Metallic or, you know, perhaps the most intimidating, the liquid salt fuel types of reactors. Nitrite fuels are out there. So there's a diversity in the fuels.

Power levels go from as low as about one megawatt thermal to well over 1000 megawatts. So you can see that, you know, the potentiality of a review may take us in the area of looking at something that's on the order of a research and test reactor. And it might be able to be approached on that type of a basis to something that's very large -- has a very large burn-up, fission product inventory that will have to be treated maybe more in a conventional sense as a large power reactor.

Submitted right now to the subcommittee and available for public viewing is our four --

(Sound system failure.)

MR. BAJOREK: Okay, are we good to go? Thank you. Okay. Strategy 2 right now has four documents that have been available for review. The first one, the introduction, kind of outlines the use of the codes. I'll talk more about that later on in the next steps. We feel that one does need some significant revision. Volumes 1, 2, and 3 lay out the codes and approach that we are using for plant system analysis, Volume 1. Fuel performance in Volume 2. Source term and consequence analysis in Volume 3. We expect to follow these up with two additional volumes. One, to look at licensing, site dose assessment in Volume 4. Volume 5, fuel cycle-related topics, those are under development. I don't have a date for you of when I think those are going to be complete.

We focused on the topics in Volumes 1, 2, and 3 because we saw these as potentially needing the longest lead time in order to get us ready for review. The idea of each of these volumes is one, to point out the specific tools that we're developing right now. And that we intend to use for non-LWRs. Point out technical gaps. And those can be either in how you use these codes to model a certain type of accident scenario. Features they need to have. Gaps that may be there in the assessment. V&V type related activities. And to the extent possible at this point, gaps in the experimental data.

And those gaps can kind of come in three different areas. There's data that may exist. It may not be in a format that we can readily use right now because, at least the U.S. data is quite old. There's data that may have very high uncertainty and may need to be improved upon. And there are some phenomenon where the gaps and experimental data say you don't have much, if anything, to go on. And we're working with Department of Energy now to try to categorize these and point out where we think some of those major needs --

MEMBER REMPE: Steve, first of all, you said something that's not quite true. I'm glad you changed the title of Volume 1. I want to say that first. But apparently, it was reissued on October 1st and you changed the title. So you don't say it's design basis analysis anymore, which I'm glad. We've harped about that for a while. But what other changes did you make? This just got issued a couple of days ago. Right?

MR. BAJOREK: Oh, that's basically it. And next steps, I'm going to talk about what we're going to do to these volumes to come up with a new revision to each one of these.

MS. WEBBER: But Joy, it wasn't reissued. He just changed the title slide to indicate that we're moving in that direction.

MEMBER REMPE: Well it says Rev 29, October 1st, 2019.

MS. WEBBER: That's just the title page.

MR. BAJOREK: That's just a very small -- that's just a very small to distinguish --

MEMBER REMPE: So really the volumes that we think we have are what we have --

MS. WEBBER: Correct.

MR. BAJOREK: Right.

MEMBER REMPE: -- and we should be reviewing it.

MS. WEBBER: Correct.

MR. BAJOREK: So the references are going to be kind of weird in our letter. Right?

MEMBER BLEY: Joy's vision is much better than mine. I can't read the slide --

MEMBER REMPE: I can't read it either.

(Simultaneous speaking)

MS. WEBBER: It's a vision of the future.

MR. BAJOREK: Yeah. We intend to change

the title of that one. And refer to it more as plant systems analysis tools as opposed to design basis. Okay? We will be revising that and the other volumes -- different comments that we've received from you and the other stakeholders and come up with a revision. But right now, what you see in those ADAMS documents, that's what's available.

MS. CUBBAGE: Yeah and Steve if I may, I'm assuming that when you changed the title to make your graphic your slide, it put an auto date in there.

MR. BAJOREK: Yeah.

MS. CUBBAGE: There was no October 1 --

MR. BAJOREK: No, no, no.

MEMBER REMPE: That's makes me feel better. Thank you.

MS. CUBBAGE: I'm sorry. But I was going to interrupt you there, but you were on a role and I didn't --

MR. BAJOREK: I'm sorry. That was --

MEMBER BLEY: As far as our use, we'll use --

MEMBER REMPE: That's what I would think. I mean 30 days is the requirement. Go ahead.

MEMBER MARCH-LEUBA: On the slide you've got, you talk about independent analysis at the bottom of the slide -- to which level do you consider being independent from the applicant, a requirement? And let me bias the answer for you. In 1960, we were designing reactors within the slide rule. And necessarily you do have to do very simplified assumptions. And that almost required you to do a separate analysis that was completely independent so you could verify the assumptions. Now we're going to the Monte Carlo analysis. We won't have any assumptions. And if you can agree that the code is good enough, what you need to review in the confirmatory is the input deck and the way they use it, not the code itself. So did you give any thought to that?

MR. BAJOREK: Yeah. That's an important topic because I think we'll see more of this. We have talked to Technology Working Group and several of the potential applicants. In some cases, they're using their own tools -- legacy tools that's easier for them to understand license and protect. Okay? They want to keep these proprietary as well. Then when we use the tools that we're using, okay, we've got that independence. We're independent at least on the codes that we're using. They both may be assessed against the same set of data and that could be limited. And that's also something that we're going to have to consider. Have we tuned them both to the same type of information? So that will be concerning.

The other aspect with these tools is that they have become in general, much more flexible and complex than what they were back when -- I actually ran WFLASH at one point. Okay? It was hardwired. There was only one way to do it. The only thing you could change were the inputs. Now there are some many switches and options and nodalization and correlations that you use. It's still very easy to be independent. And even when people have been using the same tool, studies have shown that this group of experts in the tool and this group of experts will take the same information and they will get a different answer.

Our view right now is that we're okay with that. Okay? We'll be able to be independent by us taking information and doing our evaluation. Letting the applicant do theirs and their way and then comparing things. Because at the end of the day, these tools are used, one to inform the staff, educate the staff on how the machine works or should work in the case of the scenario. Ask intelligent questions of the applicant because it's their tool after assessment and review, which becomes the analysis of record. So that's the key.

Right now we have not seen anyone who's going to say we're going to use identically the same thing that the staff is proposing. As we start to go towards severe accidents, everyone will probably be using MELCOR. Okay? So that concern is valid.

MEMBER MARCH-LEUBA: But what I'm saying is do you see independence as an absolute requirement? Something nice to have.

MR. BAJOREK: No. It's a nice thing to have, but I think there's enough flexibility in what we're doing in order to maintain.

MEMBER MARCH-LEUBA: And I support that. I'm talking about biasing you in the answer. Independence is not an absolute requirement.

MR. BAJOREK: Okay. The range of capabilities that are outlined in Volumes 1 through 3 and the preparedness here, I like to characterize as looking at the problem from two different angles. One, the Volume 1 codes are really looking at adequacy of the safety systems. Are we operating the machine within safe limits? I used the word "safety functions" as opposed to "safety systems" or an ECCS system as we're used to light water reactor. Because a lot of these plants are going to be utilizing passive safety features, natural forces in order to remove the energy and to shut down the reactor.

Regardless, the staff is going to be interested to make sure that those safety functions perform adequately, are the limits at which they operate the reactor in terms of burn or power distribution, power shifts that may occur. Are those acceptable? Are the Advanced Reactor Design Criteria satisfied? And in doing so, does the staff understand how this can -- this machine is going to work during a hypothetical accident scenario?

On the other end, okay if you do have a severe accident, the important things that need to come out of the Volume 3 methods are first of all, when is that fission product inventory? Some of these plants are going to have very high powers. They may utilize a breed-and-burn type of operation where the fission product inventory can be large. There may be a large source term. Looking at what the source term is. Where the fission products go. And the dose is looking at that from the opposite end.

Volume 2 is sort of in the middle. And that's kind of good because if we have problems, we can always point to Dr. Corson over here and blame things on him. Because we're both going to be looking at Volume 2 to help us establish the initial conditions. What is the initial fuel temperatures? What are the initial average fuel temperatures -- peak fuel temperatures, power distributions, oxide distribution should that occur in one of these types of systems.

We want to make sure we're consistent with material properties so that we're using the same type of thermal conductivity degradation in both of these tools. Because we'll frequently have our own fuel elements, either in MELCOR or the Volume 1 tools. Those should be very closely represented by a tool that can accurately show what those are.

And finally, what are the failure mechanisms? What are we looking for when we do the Volume 1 type analysis? Are we interested at temperatures at which the TRISO particles may start to come apart or other failure mechanisms that start to release fission products and go to the fission product inventory.

The role of the NRC codes with non-LWRs as part of the review, this remains to be defined. Okay? We're trying to be very general at this point. Be as generic as possible not only with the application of these codes, but also to the potential reviews that will occur. And what these codes will be needed for. We look at those as being based on the applicant's submittals. What type of a licensing strategy that they want to pursue. The perceived safety margin. We think it's going to be large. The applicants say it's large. We hope that's what that is. But that's going to be up to us to help verify.

MEMBER BLEY: Excuse me. Somebody on the phone needs to mute their phone. We're getting noise from you.

MR. BAJOREK: Okay. And finally, what are the needs of the User Offices? We may have different requests from NRR, NRO, NMSS as we start to look at fuel cycle. We are starting to see some indication of what might occur for those which are using a Licensing Modernization Project, going along that plan. And you know, we say some of them will probably go along this path. And what's kind of interesting is the points that they're reporting in these pilot studies kind of come in two different categories. We're seeing a large number of them concentrate on what I'll call the Y-axis. Okay, where they're saying that there's no dose. There's no source term. There's lots of safety margin. You don't have any kind of release.

And what we see coming out of this are

questions that involve the safety systems, those systems which may or may not be safety significant as credited to the analysis. And verification of that margin in order to ensure that, that point is really on the Y-axis. And that you don't fail an additional barrier. And that point move over to the right close to this not an acceptance curve, but the frequency consequence target. There will be other cases out there --

MEMBER PETTI: Steve, can I just ask a question? I understand your thinking on this. So here's a case, you know, there's no release. Okay? Let's say the fuel does release something, but the system doesn't, you know, open up and so a valve doesn't open. It stays below a set point. In your thinking of the confirmatory, would you just then look at that and say well all I have to do is the thermal-hydraulics as the first cut. And if I can show the pressure doesn't leave the relief valve, then I'm good enough? Or will you guys go and also try to do the fission product release as well? Because you know, they're acceptable, wherein light water reactor, they may not be. So have you thought about how you're going to really slice that up?

MR. BAJOREK: We think that using the LMP, you do enter a potentially grey area where there is potentiality that the systems analysis codes, they may say sorry, we have large uncertainty in the performance of the safety system. It's large enough that we feel that looking at the source term and tracking the release is very much warranted. And then of course, we would do that to full source term type of calculation using MELCOR. I think the real answer is going to come in how much of that margin is really there, okay? And --

MEMBER MARCH-LEUBA: By margin, you mean Y-axis or X-axis? Frequency or consequence and don't tell me both.

MR. BAJOREK: Possibly both. Possibly both. For those on the Y-axis, it's going to be more -- it will be margin to whatever that next barrier or barriers happens to be. We would anticipate the questions.

MS. CUBBAGE: I wanted to add something here. Are you speaking more from the perspective of what the staff will do or the applicants or both?

MEMBER PETTI: The staff --

MS. CUBBAGE: What we will do. So I think given that the staff tends to explore sensitivities and explore margins and maybe go a little beyond, we may want to look at additional studies, even if it's shown that the system is intact. But I mean I would expect that applicants are going to truncate and say, okay we haven't breached any barriers. You're not going to feel a full blown -- you could stop.

MEMBER PETTI: Right, but this is a multidimensional problem. Right? I mean you could decide just to exercise the system code --

MS. CUBBAGE: You could.

MEMBER PETTI: -- convince yourself you understand the --

MS. CUBBAGE: You could.

MEMBER PETTI: -- reactor.

MS. CUBBAGE: In a perfect world, that's the end.

MEMBER PETTI: Right, that could be the end. As opposed to then going in this other dimension and parameterizing all the fuel behavior, the fission product release.

MS. CUBBAGE: Right.

MEMBER PETTI: I mean, you know, this is all in the context of the quicker licensing. You know, you've got to think about -- think about things in a different way in what you're going to do and what you're not going to do.

MS. CUBBAGE: I think typically we'd be in where your thinking is. But then if we are seeing that there's not a lot of margin, then we might start to explore.

MR. BAJOREK: Yeah, I think we're going to -- it's going to depend a lot on the submittal and where we see that fitting in. And as I said, there may well be that grey area where we're going to have to do both in order to ensure that there is the public safety. And that we're confident that the system is working the way it is.

MEMBER MARCH-LEUBA: Even for advanced --

MEMBER PETTI: I just think, you know, you're going to have to really recalibrate your thinking in how your approach a problem. Right? Because it's not like a light water reactor at all, any of these.

MR. BAJOREK: And they're each going to be different in and of themselves.

MEMBER PETTI: Right, yeah.

MR. BAJOREK: And so it's almost, you've got to, you know, handcraft the approach to the technology.

MEMBER PETTI: And that's what I was sort of getting at in the earlier slide. That you may have some that look much like a research and test reactor. Okay, there's very, very little burn-up. There's huge margins. You may be able to limit the review in looking at a certain class of accidents. There's going to be others, maybe out here by the case here that I label as a non-zero dose where you know, say example in a gas-cooled reactor, you're going to have some circulating activity. You may have graphite dust. You've got a high initial system pressure.

In some of those scenarios, yes, you are going to have a significant consequence and potentially a dose. In that case, the question's going to be what are the uncertainties one, in evaluating with that source term, okay, and its consequences. That sort of uncertainty on the Y-axis. And what is the uncertainty in my PRA, which is on the Y-axis? Because the staff is going to be concerned that in that little square box that's drawn there, is that star closer to the lower left-hand corner or potentially over in the upper right-hand corner? Because it's more frequent than we anticipated.

The consequences are worse such that it now becomes a risk significant type of scenario. And that's probably one where if we see things like that, I would anticipate that the focus of the activities then goes on source term consequence and dose. We may not be as concerned on the systems analysis at that point except for other types of scenarios.

MEMBER MARCH-LEUBA: But even for advanced LWRs that we're seeing right now, all of this is coming out not only on the Y-axis, they're coming on the white area.

MR. BAJOREK: Right.

MEMBER MARCH-LEUBA: Basically if you believe that, then you don't need to do any confirmatory calculation. Because there's no probability or frequency, and no consequence. How much confidence do you have that the analysis that the applicant performed is not really a box like the one you're showing on the document.

MR. BAJOREK: That's where the challenge is going to come in the review.

MEMBER MARCH-LEUBA: Is there a way to do a simplified cheap calculation, bounding -- more like in Appendix K, there's some best testament without having going to into a Level 3 BRA with 150,000 milligrams?

MR. BAJOREK: If you hold that thought, I'm going to be talking -- What we're going to do is I'm going to talk a little bit about Volume 1, then we'll do Volume 2 and Volume 3. I'm going to show an example in how we may be able to step into that type of a --

MEMBER MARCH-LEUBA: I'm not against cheating. I mean if you can do a simple calculation of this, which says for sure, it's not graded on this. I don't know how low it goes, but it's not graded on this.

MR. BAJOREK: We are not opposed to doing a hand calculation if that's sufficient. In fact, I think it was a couple of weeks ago, we gave one of the subcommittees a report on GSI-191. And one of the sections in the back, how much entrainment do you need to show that you aren't going to precipitate? That's a hand calculation. Okay and if we can do that, we'll certainly go ahead and do it.

Let's go on then unless there are -- any more questions on this? If that's the case, what we'll do is we'll start --

MEMBER KIRCHNER: I mean just an observation, not a question, Steve. If you look at 10 CFR 52, which a number of people are considering as the regulatory basis for applying, no matter the option you pick, basically you make the assumption of a major hypothetical accident. And then you do a dose assumption subsequent to release. So I think that's the back of the envelope simplified assumption to bound a problem when there's large uncertainty or the PRA isn't mature enough. Yesterday we had a full presentation on PRAs for these applications.

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

MEMBER KIRCHNER: A long list of all the issues in terms of uncertainly and how mature the PRA is as you enter into this kind of approach if you're using the LIM option.

MS. CUBBAGE: I'd just like to address that for a moment. The regulation that you're speaking to, while it doesn't explicitly say it's applicable only to LWRs, we're exploring whether advanced reactor applicants would need exemptions to that.

MEMBER KIRCHNER: I would guess they would.

MS. CUBBAGE: Yes. Okay, so I just wanted to make sure it was clear that it's not 100 percent decided that, that regulation and the way it's worded would apply. Because while it doesn't say LWR only, the language is very LWR-centric talking about demonstrable leakage into a containment, et cetera. So it's not directly applicable.

MR. BAJOREK: Okay, what I'm going to do next is talk very briefly about the plant system analysis codes that we have discussed in Volume 1. We've researched a very large number of codes; USNRC, some international codes. And tried to select ones -- a limited set that will allow us the flexibility to do a very broad number of designs. And we've decided that essentially a combination of some of the NRC tools and tools primarily by NEAMS because they focus more on Gen IV systems in their applications. This one appears to be one that would give us the capability for these broad number of designs and meet the schedule that we anticipate.

Volume 1 documents what we can BlueCRAB suite of tools. That's what we're calling it. And that's just a pallet that shows you everything that potentiality would be used. We wouldn't use all of those for a particular design or evaluation model. It's a limited subset. And I'm going to step through an example on that.

The main purpose of Volume 1, as well as the other volumes are to try to identify what are the technical gaps? What do we need to resolve here over the next year or two so that as these applications come in and we get in to the review, that we understand what needs to be resolved. We've based this on review of available PIRTs where experts have gone and looked at each one of these systems for plausible scenarios -- accident scenarios. What are the physical phenomenon and what are the features that you need to be able to analyze to in order to get a reasonable answer? So we've used those as the basis to identify these gaps in terms of the modeling, experimental data, and V&V.

We feel that the codes, which are outlined in BlueCRAB are applicable to all the expected designs. And we outline ten unique design types that are potentialities at this point. I'm going to step through one we're working on right now. And as of yesterday, we are running in-house on a microreactor. The topic has come up on a few times on complexity. And we understand, you know, the concerns on here. Because I think in the developer's for some of these tools like to show how detailed they can be. It's a feat of software engineering. But it's not something that we have to use as part of the review. So when we develop these models, we do not expect to develop high resolution models where you're modeling every pellet as you've some of the CASTLE tools being used for. We would expect to do things where we only put the detail where that is needed. That might be the hot spot, either in the vessel or the fuel, depending on what that technical or regulatory issue is. So the guiding principle is that of KISS, Keep it simple, Steve. And then add the detail as -- I have to be careful when in the record here -- But add the detail only as the regulatory issue or the technical concern demands it.

If there is something that gives you lots and lots of margin, you don't need that geometric detail. If there's lots and lots of margin, it also makes life simpler because there's some physical phenomenon that might be very difficult for us to analyze that we may be able to be bound or use a simplistic model. So that's our going in approach for applying these types of tools.

This figure shows the tools which we are working on and developing. It addresses the features. It uses the MOOSE framework as a way of coupling things together for those applications where tight coupling is needed. The applicants in our review of the PIRTs saying there are some cases of molten fuel salt reactor for example, where having this type of coupling is very important. Looking at a microreactor, also has its needs for a coupling. But I'll show you how we can simplify this. So we would start with this and then pare this down for the given application to come up with an evaluation model.

MEMBER MARCH-LEUBA: While we have this slide, let me go back to a question in this area. The white codes or the DOE codes --

MR. BAJOREK: Right.

MEMBER MARCH-LEUBA: -- and the reactors are somehow supported by DOE and national labs. And they're likely to use the same code. At which point do you see the fact that they're using the same MOOSE framework that you are for confirmation as a problem.

MR. BAJOREK: You see it in some cases, but I think of the applicants we've talked to, most of them are taking their own approach. Okay? There are a couple which are using something very similar to this. But there again --

MEMBER MARCH-LEUBA: Do you see a problem if an applicant -- we used to call Jo's reactor decided to use BISON and we use BISON too. Would that be okay?

MR. BAJOREK: If we need to go into that detail. One of the -- One of the avenues we have -- there's two fuel performance codes on there; BISON and FAST. And we're still working to get FAST coupled in with the MOOSE framework. If someone wants to use

BISON, we can go and use FAST. If someone uses --

MEMBER MARCH-LEUBA: Let me just give away my final -- I don't think there's a problem with using the same code as long as the code is validated and hopefully is. Ninety percent of the sources of error is not the codes, it's the user.

MR. BAJOREK: It's the user.

MEMBER MARCH-LEUBA: So just having a different user. You've seen in the past, applications where we use two different codes. One at NRC and one -- And we take the same today and convert it.

(Simultaneous speaking)

MS. CUBBAGE: I'd like to chime in on a licensing perspective. We also use applicant's code and applicant's input data and we exercise them and make sure we understand how they work and we do sensitivities. So that is definitely a viable option for the licensing office.

MEMBER MARCH-LEUBA: We don't see a problem with doing that.

MEMBER REMPE: I agree with you. And I've heard Amy say in the past, NRC doesn't have to have a validated code. But if an applicant comes in and --

MS. CUBBAGE: I didn't say we didn't have to have a validated code. I said we may or may not do calculations. And we are not subject to Appendix B, et cetera, et cetera. But if we're going to use a code, we need to have comfort that it's been validated.

MEMBER REMPE: You have to have comfort that's it's been validated. And that's I think a very important point because if an applicant with Jo's Reactor comes in and uses the BISON code, which has not been validated for the conditions of interest and NRC can't use FAST because it's not validated for a molten salt something or other --

MEMBER MARCH-LEUBA: And the applicant cannot use it here.

MEMBER REMPE: Yeah. And so that really needs to be emphasized if we go with this approach, that applicants better be careful that the code is validated because this will catch us. And that warning just needs to be emphasized throughout this discussion.

MEMBER MARCH-LEUBA: And the point I'm trying to make is there are two issues. There's validation. There is independence.

MEMBER REMPE: I agree with you.

MEMBER MARCH-LEUBA: And if you have to weigh them, you'd have 90 percent validation, 10 percent independence or 95/5.

MR. BAJOREK: Validation is vital. I mean we're working on that. We'll be doing validation to our satisfaction that we need to have our codes validated to. Applicants are likewise going to have to validate their tools. If they validate some subset of this, the burden's on them to make sure it's eventually satisfactory to the staff.

MEMBER REMPE: And I know you're doing it from the reports. But when you're trying to consider all the field of reactor types and things, it gets to be very long list of things. And boy, it would be nice to have --

MR. BAJOREK: Yeah, it's difficult for us --

MEMBER REMPE: -- prioritization.

MR. BAJOREK: -- to try to swallow the whole hog at once.

MEMBER MARCH-LEUBA: But that's where the --

(Simultaneous speaking)

MR. BAJOREK: Right. And we're working with Department of Energy. And we're pointing out where the validation -- the assessment needs to be. And for the designs that look like they're coming up, they're working on those. And we're working with them. They're doing much of the assessment. We're doing some in-house because that's how we educate ourselves by setting up some of our own models.

MS. WEBBER: But Joy, to your comment. This is Kim Webber. To your comment about prioritization, so we do have a prioritization. We have limited resources. And so by the very nature of limited resources, we have to prioritize. And so I think the introduction does characterize our general approach of prioritizing those resources. And so your point's well taken that we just don't -- we can't work on everything. But I think what Steve's laying out here is a framework that we will work on over a period of time as resources become available. And as applicant's identify themselves as serious.

MEMBER REMPE: And we've discussed this before. I'm just reacting to the bullet -- or sub-bullet that said all plant designs considered equally likely for DC. And so just kind of be careful on how your characterize it is where I'm coming back with it.

Then also, sometimes I hear well okay, so the codes haven't been validated yet but we get wonderful insights when we use these multi scale codes on what experiments are needed while relying on invalidated codes for those insights could be a trap. And that's a point that I think ought to be brought up at the full committee meeting, which I know we've mentioned it before.

MR. BAJOREK: That's why when we start to look at assessment, we go to the PIRTs first. And if the PIRT team has identified certain phenomenon or processes that you need to validate against, that's what we're expecting to come out of the code assessment, at least first format. It's not really using the tool -- the code to do a prediction. And then say that was important because the code said so. No, it really starts from the PIRT and hopefully the code is giving you the same thing. Okay --

MEMBER MARCH-LEUBA: I apologize. I was not in the subcommittee meeting, so I'm wasting some of your time now. I'll go real fast. So I wanted to bring a different subject. You're the code guy and I'm a code guy. So we concentrate on fidelity or demonstrate conservatism. As long as that happens, you're happy. But if you talk to the Chapter 15 review guys, they've spent enough time, mad, arguing about the failing calculation, but arguing about that sequence of events. Did they assume all the failures that were supposed to assume? Did the boron dilutes in this corner and it doesn't go. And that's something that we should be able to do. And that's something that we end up spending more time than running the calculations.

MR. BAJOREK: Yeah.

MEMBER MARCH-LEUBA: You should be ready for it.

MR. BAJOREK: Well I guess sort of -- and this is a little bit of my philosophy is that when you do an analysis, you want to start off with sensitivity studies and certainty calculations if you can do that. And hopefully from those, they start to point to certain processes and phenomena that tended to dominate the calculation. We may not necessarily believe the code in all cases, but that can help guide the review to look at certain things. So as we start to use these sensitivities and uncertainties, are certainly going to be one of the things.

MEMBER PETTI: So Steve, have you given any thought to really doing a pilot on this to run front to back on a couple of concepts?

MR. BAJOREK: Yeah, we --

MEMBER PETTI: -- because a lot of this is -- it's sort of at 100,000 feet. And you know where the problems are where the rubber meets the road.

MR. BAJOREK: We made a suggestion a few weeks ago after looking at some of the LMPs that because this is such a different departure from the way the staff has done things in the past, the staff should do a pilot study. Step through a Level 3PRA, apply these tools to some design that's out there that we gain information through. And step through the process.

When the staff did the 1988 Appendix K rule change to go from Appendix K to best estimate, they used the CSA use study as a way of providing guidance, not only for what industry was doing, but also kind of to help when we came in with the application later on. The reviewers always were going back to that initial pilot study as a way of how they should even conduct the review. So I agree. I think something like that should be going on.

MEMBER PETTI: The only other thing I'd say -- You know, you mentioned earlier about using the PIRTs -- I call them the headlights to figure out where you're doing.

MR. BAJOREK: That's a good point.

MEMBER PETTI: I worry that the one that I was involved with on TRISO is now approaching 20 years old. And frankly, much of what we thought back then, we've proven to not be correct. So somehow we have to have a feedback loop. You know, because you're going to look at them and I'm going to go well no, well that's not right. Thinking has changed today to tell us something different. So there's another inter loop around here that adds complexity.

MR. BAJOREK: Well we very frequently -- We're using these PIRTs because that's what out there. In a couple cases, we've done some studies on our own with molten salts to get us up to speed. But we would anticipate as the design comes in, we may do another independent PIRT. We'll look at what the applicant has to say because they're at least using the most recent design information. We may do our own internal one. So those PIRTs will be revisited as part of our exercise.

MEMBER PETTI: I mean it's the one area where there's actual R&D going on. And so it is now in the field of reducing uncertainties.

MS. CUBBAGE: One thing I wanted to mention is that Hossein can provide additional detail, but we are -- the Office of New Reactors is contracting in consultation with Research to do some sample calculations using MELCOR for the three technologies to run it all the way through. So we're planning to do that in FY20.

MR. BAJOREK: Okay, let me run through --

MEMBER KIRCHNER: Can I just ask a question?

MR. BAJOREK: Oh, sure.

MEMBER KIRCHNER: I should have pointed this out at the subcommittee meeting. I think you have this. Do you have a finite element code in-house or commercial product that you have access to? Do you have a license?

MR. BAJOREK: We use COMSOL as one. I think --

MEMBER KIRCHNER: I was going somewhere with this. And that is with the microreactors, what I found, we used ABAQUS on --

(Simultaneous speaking)

MR. BAJOREK: Yeah, yeah, yeah.

MEMBER KIRCHNER: -- to do the detailed analysis. So when you have a quasi solid state reactor, then it may prove that a finite element tool is the most useful way to do your bounding confirmatory analysis.

MR. BAJOREK: MOOSE is a finite element tool.

MEMBER KIRCHNER: Forget Moose. There are good commercial products that are simpler to use.

MR. BAJOREK: You know, that gives us the capability. Now I think that if I were off doing my own microreactor, COMSOL would probably be the way to go. Okay? Because remember, we're using MOOSE not only for the finite element capability and the tensor mechanics. But also to handle all the data transfers between these other tools. And it's already -- they're available to us.

All right, well -- Okay --

MEMBER KIRCHNER: There are commercially available tools that are simple to use that may be just what you need to do your confirmatory analysis without getting involved in MOOSE.

MR. BAJOREK: There are other ways to do these, yes.

MEMBER KIRCHNER: Okay.

MR. BAJOREK: Now just as a quick example on how we would simplify this, we are looking at a microreactor. We've developed a model, worked with ARGON. We're running this model now. It does not use all of the tools that are available in BlueCRAB. Okay? We use SERPENT to develop the cross sections. That feeds the MAMMOTH code for doing the neutronics. Now a microreactor is interesting because what really shuts down is the radial and the axial expansion of the core as it heats up. That gives you the negative reactivity that shuts the system back down. So you need to have this active coupling between a kinetics tool and your tensor mechanics.

We put SAM on here. It's not really doing a system or a hydraulic. But what we're using that for is a very simple model of the heat pipe. Okay? Rather than trying to model a heat pipe with a SOCKEYE or another sophisticated code, we said hey, it's just a superconductor. So we take a heat structure in SAM, we put in a very high thermal conductivity to give us the effect because one of the accident scenarios, we want to look at anyway is going to be loss of a shutdown -- or loss of your shutdown heat removal. The heat pipes don't do anything except act as a source of stored energy in that. So you know, we simplify what we do in SAM to get the heat removal. We understand the tensor mechanics and the neutronics. I wouldn't say it was trivial to set up, but we already have the model. We're up and running. We're doing that right now.

Now do we need to use FAST or BISON on this? Well at this point, we're saying no. We can handle the material properties through our common heat structures that are available in the other tool. If we get to the point where we have to have the details from a FAST or a BISON, we could turn on that link. But in the interest of simplification and keeping it simple at this point, we're not building that complication yet. We'll wait for that.

We would expect however that some systems -- and boy, the title's really got clobbered on this -- they might come in with a reactor cavity coolant system. We've already completed the link to MOOSE with the TRACE code. So if we're looking at an RCCS, typically water cooled, we can handle that with TRACE. We know how to model those types of things. And we're confident that TRACE has the basic assessment to handle water boiling in a tube. If you have a gas cooled reactor, you might use some different tools and we have a Rankine Cycle. And that's where we bring in TRACE.

So in our evaluation, we have all the features that we need to deal with this broad range of plant designs, which are coming in. Our approach is to keep it simple. Build in the complexity as we need to as we go along. And be ready for when any of these review eventualities.

With that, unless there are any more

questions on Volume 1, I'm going to turn it over to James Corson. And he is going to bring everyone up to speed on fuel performance. Thank you.

DR. CORSON: Okay. Yeah, I just have a few slides on fuel performance. I feel like I was just here recently with the subcommittee. Some of you weren't here, but -- some I'm going to go through kind of a high level overview of what's in Volume 2. And if you have any questions, of course, feel free to stop me.

So first to start, I just wanted to go over on this slide why we're doing this or generally how we do a fuel review. So for advanced reactors, we've put out Reg Guide 1.232 and that proposes some advanced reactor design criteria for non-LWRs. And in a lot of ways, they just mirror the general design criteria. So of course, you know, vendors can use these ARDC, or they can develop their own plant-specific ones. But generally what we would do when we're reviewing an application is we verify compliance. And for the fuels area, the main criteria are no fuel failure during normal operations. And you always have to be able to shut down and cool the reactor. So that's what we're really verifying when we look at the fuel review.

And typically we use fuel performance codes to help with these reviews. We don't necessarily need to do this. As Steve says, sometimes we can just do hand calculations or simple analysis. But oftentimes it helps to have a fuel performance code to look at some sensitivities or uncertainties.

So how do we typically support our user offices, NRR and NRO? So the way we plan on using FAST for non-LWRs is going to be very similar to how we use it for LWR analysis. So we have two main approaches that we take. The first approach is the single element just looking at one fuel rod or one fuel element, whatever it is for a non-LWR. And making sure that the safety limits are met during normal operations or an AOO or a mild transient. So we don't see that changing for most of these non-LWRs. We still anticipate having to do this sort of check that their fuel doesn't fail during normal operations.

The other way we use it is in conjunction with Volume 1 codes or with TRACE in the case of LWRs where we're providing initial conditions for an accident full-core type analysis. So again, we don't see that really changing as Steve really went over in his presentation. We still expect the fuel performance code to support the accident analysis.

Now the way that FAST interfaces with other codes, typically for LWR is we just manually transfer information. So we run, you know, get the initial conditions and manually feed those into TRACE. That may be sufficient for some of these non-LWRs. We may be able to take this very simplified approach. But we're also working on directly coupling the codes as Steve has mentioned, in case we need a more detailed analysis. Right now we don't know exactly what the applicants are going to come in with, so it's beneficial for us to be ready to be able to do this.

So right now in the fuels area, our main focus is on metallic and TRISO fuels. So molten salt -- I said this at the subcommittee meeting, but for people who weren't there -- for the molten salt fueled reactors, we're not using a fuel performance code like FAST or BISON. Those are thermal mechanical codes where you have some solid rod, whatever. So we're not looking at that with FAST. Of course, you know, Steve and Hossein are talking about what we'll do for those types of fuels.

MEMBER MARCH-LEUBA: So how does FAST calculate on this side of a fuel failure? And let me bias you on this. Let's consider the reactivity event section with the famous 280 calories per gram or whatever number is today. How would FAST calculate that? It relies on experiments.

DR. CORSON: Yeah, so I mean there's different like failure criteria for these scenarios. There might be like a maximum strain. So you calculate a certain amount of strain in your rod. And if it exceeds that, you say it failed. And that's based on -- yeah, like the clad for an LWR. So again, that's based on a lot of experiments. I mean you could have something simpler like does your fuel melt? I mean that's a little more straight forward.

MEMBER MARCH-LEUBA: You don't need FAST for that one.

DR. CORSON: Yeah, you can just do a simple how much enthalpy did you add?

MEMBER MARCH-LEUBA: That's --

DR. CORSON: Yeah.

MEMBER MARCH-LEUBA: So the point is, what Dr. Rempe says all the time. You do need experiment. You can have experiment with a code. And typically once you have sufficient experiment on it, you end up with rules of thumb like 280 calories per gram.

DR. CORSON: Yes, exactly. Exactly like what you said. And you know for like TRISO fuel, you would use something like the Weibull statistical parameter. And again the parameters in that distribution are from experiments that we find and narrow down and then apply to our code.

So the last slide I have is just talking about where we're currently at with FAST. So it's underacted development. Metallic fuels, we're in very good shape. We've already done some preliminary assessments. There are some models that we can improve. But for the most part, we're in really good shape for metallic fuels and don't have too much more to do.

So for TRISO fuels --

MEMBER PETTI: So can I just -- Are you able to calculate the swelling and interconnection and fission gas release?

DR. CORSON: So we have the very simple model.

MEMBER PETTI: -- the big safety, but you've at least got something in there that --

DR. CORSON: Yeah. So for fission gas release, we just say it releases X amount. So it's like 70 percent. And generally that is actually pretty good.

MEMBER PETTI: -- when you get to a certain swell.

DR. CORSON: Yeah. So we do have simplified models for that. That I think is the main area for improvement -- to improve those fuel swelling and fission gas release models. But we do have simplified models in there right now.

So TRISO fuels we're further behind. But we have a plan for how to deal with that. And fortunately we have the PARFUME code to rely on that has a lot of the necessary material properties, the necessary models that we can use and apply to FAST.

We think we're in very good shape as far as experimental data out there for validation. Of course, EBR2 ran a large number of metallic fuel, U10s, or cases, pins. So A&L has this experimental database. Right now, we're looking to get access to that. We think that will probably be sufficient. And then we can perform additional sensitivities and uncertainties to explore, you know how manufacturing might affect things or so on.

MEMBER PETTI: I mean, you know that those -- the radiations of the thermocouples.

DR. CORSON: Yeah. So that is something I thought I'd add.

MEMBER PETTI: I saw that in the write-up. I mean, how are you going to deal with that?

DR. CORSON: It's difficult. I mean, you know, so many of these things are temperature dependent. So if you don't know exactly what the temperature is, it places a large uncertainty on your results. And I think that's how we're going to have to handle it is with some uncertainty. Yeah, I didn't point that out there, but yeah, I mentioned that in the report.

And then yeah, for TRISO fuel, we have the ongoing AGR fuel qualification program. So we're going to rely on that quite a bit. And some of those are radiations and PIE have already been completed for that. So we think we're pretty good.

And then the last thing here, of course we are still working with the BISON team. The one area where we really think we can collaborate a lot is on validation. So there's still -- DOE is still doing their own development. But we really want to work together with validation to make sure that we're confident in both of these codes. Because in some cases, we might want a more detailed code like BISON as Steve had in his CRAB diagram.

So that's all I had on fuel performance. If you have any questions, I'd be happy to take them. If not --

MEMBER PETTI: So let me ask you a question.

DR. CORSON: Okay.

MEMBER PETTI: I'm been involved in the AGR program. There's a chance that they'll come in purely with the data and develop what I'd call empirical models. And just argue that the data show is the failure rate. You know, I have a model that does all the thermal mechanics, but I'm not going to go there because it's difficult to validate, you know, these little coding layers. And they're not really adding to our understanding, we've done all these radiations. So you guys ought to have an option to be able to go straight to the source term. Because if you assume the failure rate on input, you bypass the thermal mechanics. Just assume it fails at that rate and go from there.

DR. CORSON: Yeah, and I think we do have that approach.

MEMBER PETTI: I mean how did the simpler approach, whether -- you're not going -- Because you know, there's not an ARDC about fuel on HTGRs. It's all about the circulating -- the activity. Right? So it's all about the source term. So there's a less of a reliance in that community. The whole thing is to show the fuel doesn't fail in the envelope. And you've done that. And then you go from there.

MR. BAJOREK: Would you expect to fail during operation or do you think most of those failures are going to come from manufacturing defects? So you may know that right off, but --

DR. CORSON: You know that right off. You test as best you can and that statistically limits you. You see zero out of how many? There's your initial condition. And actually in accidents, they don't think they fail anything either. You know, so it's just a different mindset in terms of how you have to think about it to make sure the codes have switches so that you can do these simpler things --

MEMBER KIRCHNER: I think Dave, that's good advice because in the final analysis, it's all going to be the manufacturing as you suggest and the quality.

MEMBER PETTI: Now the one thing --

MEMBER KIRCHNER: And what you start with is going to then create your circulating inventory laid out, your others -- But if you've bound the problem based on experimental data, you probably don't need a detailed model of the TRISO particle.

MEMBER PETTI: Right. The other --

MEMBER KIRCHNER: And you do macro calculations thermally to show that you're within your database.

MEMBER PETTI: What about molten salt cooled TRISO designs? Have you guys given any thought to some of the differences of modeling that? Because you said you got TRISO fuel models. But I would anticipate that you might see the molten salt cooled option coming in earlier than others.

DR. CORSON: So I'd say as far as fuel performance, it doesn't change a whole lot. So you have a different thing at the boundary. You have a different coolant. And so you do have to consider whether you get penetration of the salt into the fuel that would affect things.

MEMBER PETTI: That's the thing.

DR. CORSON: And now, from what I've seen from MSRE, they didn't see a whole lot of penetration of salt into the graphite. But of course --

(Simultaneous speaking)

MEMBER PETTI: -- and the Chinese -- you should check the literature. The Chinese have done a tremendous amount on this infiltration of the salt into the pebble -- into this porous graphite. I think it's a problem that the designer has to -- the applicant's going to have to deal with, whether it be another coating on their pebble or something. But it's something you guys ought to be aware of.

DR. CORSON: Yeah.

MEMBER PETTI: Because that would be a really difficult model.

MEMBER KIRCHNER: And is that database available?

MEMBER PETTI: I've seen it -- I've seen the stuff published.

MS. WEBBER: Dave, it would be helpful if you could just point us in the right direction.

MEMBER PETTI: I just in general looked at materials. There's a number of those.

DR. CORSON: Yeah, we're generally aware of the issue. I haven't seen that particular --

MEMBER PETTI: There's a couple papers out on that.

MEMBER MARCH-LEUBA: We have a limit of the staff that wants to contribute?

MR. TRAVIS: Yes, so this is Boyce Travis, NRO. I want to correct something that was said earlier with regards to ARDC on fuel for MHTGR. I mean there is ARDCs related to fuel for MHTGR, specifically talking about SARDLs, specified acceptable radionuclide design limits. And that could include the reactor coolant boundary. It could include just the fuel boundary. It would depend on the approach the designer takes.

Separately from that, we have a topical report in-house from EPRI for qualifying TRISO fuel. And I think it sort of lays the foundation for the approach that Member Petti was talking about with regards to using the data set on a more empirical approach. And that's something we're fully prepared to pursue, depending on the outcome of that report.

MR. ESMAILI: Okay, good morning. So we talked a lot of about source terms. And I'm just going to actually talk about source terms here.

This is just a very summary of what we talked about on May 1st. And I only have three slides. So I'm keeping it simple, Hossein. So when we was talking about the source terms, we are actually considering radioactive release of materials from an overheated fuel, either into the containment or the environment. And so what you're concerned about is what is the timing -- the duration of this release? What is the chemical form of the radionuclides? And what is the magnitude of this source term? Because that has quite a bearing on, you know, what the consequences are.

The importance of this source term is well known. And we have talked about this over the past year. And we use it for safety and environmental reviews. For LWRs, we have a Reg Guide 1.183. It provides a good summary of, you know, what the regulations are and how to do different things in terms of controlling equipment qualifications, et cetera. So when we do source them, how we evaluate the source term has evolved over the years. Now we actually have best estimate computer codes that can mechanistically model the release and track the movements of this radionuclides that goes from the primary system into the containment and finally into the environment.

Of course we rely on experiments because we have to validate that model. We have to have some confidence that the code is doing what we expect. And the risk-informed approach requires selection of accident scenarios. We kind of talked about this on the EPRI diagram. So that relies on the PRA. And in my opinion, what LMP does is just brings the PRA up front. But in terms of what you need to do in terms of quantification of source term, et cetera, we are just doing what we are doing for the LWRs.

So in terms of characterizing the source term, they are phenomenal and actually there are basic modeling frameworks that are common to both LWRs and non-LWRs. I talked about that on May 1st. And it is here that we can leverage, you know, many decades of model development, research, validation, et cetera and extend it to non-LWR applications. So that's why we think -- So when we approached this a few years ago, we think that for source term and consequence evaluation, the best course of the action is to use our existing tools. And these are SCALE, MELCOR, and MACCS.

For some technologies, HTGR, the models are ready to be tested. We spent quite some time, you know, ten years ago, developing these models. And right now, we are ready to test these models. Of course, we need data. But we just want to see how these -- how this machine works.

So our approach -- our technical approach facing framework is similar to LWRs. This is what James was talking about. We do need to worry a little bit about adjustments for different technologies. For example when it comes to HTGRs, I have a more elaborate initialization of the problem because I have to do some processing of the fuel and some processing of, you know, what is the gaps in the primary system, et cetera. But the basic idea is the same.

SCALE, it will provide us the necessary input. This is the fission product inventory, the decay heat. This is going to go both into MELCOR and MACCS. For MELCOR, we need you know, inventories in terms of actual masses and decay heat. For MACCS, we need inventories in terms of activity, et cetera. MELCOR will then predict the fission product release if there is one from the fuel. And the release to the environment, that becomes a source term input to MACCS. And then MACCS does what it does best, predicts the consequences of an accident and gives us health and economic consequences.

In Volume 3 of the report, and we've gone into some details during the May 1st meeting, it provides a detailed development plan. As I said, what is our selection criteria? You know, we have staff familiarity, domestic international use. We have a large number of code users, worldwide that are currently using the code. Life cycle development and maintenance once we can actually use the code for both LWRs and non-LWRs. So whenever we do changes, it's going to benefit both technologies.

We talked about existing capabilities,

modeling gaps. This is basically using the PIRT. But you also have expert judgements. You know, we don't go over everything that's in the PIRT. We just pick and choose what is important. Data needs modeling parameters and validation basis, these are all discussed in Volume 3 of the report.

So what are the code attributes? I guess I refer to this. So when it comes to this code suite that we are planning to do, it's technology-inclusive. That means I can apply it to LWRs and all the other technologies. It's the same code. If I want to go from an LWR to an HTGR in terms of even the input deck, there are minimal input deck changes. Because the code knows that either you're talking about the LWR versus HTGR or SFR, et cetera.

It's a best estimate state of art. You know, we are keeping it simple again. This reflects the current scientific knowledge. This is supported by experimental observation. The code is integral and you have integral code because there are feedback among immunological models. The current focus, and this is -- I think Amy talked about this. So right now, as we are -- So in the Volume 3, we discuss, you know, what are the models that will be required to put in. So we broke it up into FY18, 19, 20. There are some modeling work that's still going on. But as we are putting some of these models, we are also planning to do entire full plant demonstration calculation. This is going to help us in terms of you know, testing the models, et cetera. And it involves development of the input models, running simulations, doing sensitivity calculations. And I think this is very, very important. This provides, under role of this modeling parameters and system interactions, I want to see, you know, are there like clippage effects? You know, if I choose this parameter if I don't have the data in terms of effective temperature for example, if I change it, am I expecting something different? You know, how does that --

So this gives us a lot of information. And the other activity we are involved in is data transfer interface between SCALE and MELCOR. This is data that's coming from MELCOR is going to be written in a form that MELCOR can understand. So we are also maintaining what we are actually doing right now in terms of --

And so MELCOR, MACCS interface is already an existing capability. So we don't have to worry about that. So the source term that's coming out of MELCOR goes directly into MELCOR and to MACCS.

And for some of this, I can jump on. At May 1st, I talked in detail about this. And this is something that we are currently working on, near-field atmospheric transport is exploring, you know, options, et cetera. And what is the best way of treating this within the MACCS scope.

MEMBER REMPE: I don't know if this is a good time to interrupt you or --

MR. ESMAILI: I'm done, so you're not interrupting me.

MEMBER REMPE: Okay. Now I wanted to go back to your current focus about the full plant demonstration calculations. Can you elaborate, are you doing a microreactor that's a molten salt one? And can those calculations help you gain insights, as well as the other ones if you go through for each technology what the demonstration calculation is evaluating in an overall global sense. You think it will give us some ideas of when you might need more detailed modeling. And when you think, this is going to be good enough unless --

MR. ESMAILI: That's the whole idea. That's what I was saying about the sensitivity calculations will tell you how this system works. And do we need data? Do we need additional validations, et cetera?

So right now as a first cut, the technologies that we are looking at is the microreactor. We don't have -- the extent that we can get design data. You know, we had a public meeting at the NEI headquarters last month that we discussed if the vendor's coming to get some design information, we take that design information. If not, we use public information. For example, megapower, the UC Berkeley, you know, for the FHR. And we already have a detailed model for HTGR. So we're going to build on that. So I think what I --

MEMBER REMPE: Go slow now. You've got a megapower microreactor. Is that what you said?

MR. ESMAILI: Yes.

MEMBER REMPE: And you've got a molten salt, the FHR, and some sort of NGNP --

MR. ESMAILI: PBR-1400.

MEMBER REMPE: PBR-1400, okay. And then I did hear you say the importance of getting data. What I didn't hear you say is it could tell you whether you need a finer tuned model or not. But you think it will give you some insights on that.

MR. ESMAILI: This is part of the exercise. I mean I heard all the comments. I think right now, we are putting a lot of effort in terms of making our codes ready. And as a part of this process, we are learning what is important, what is not important. You know, do we need experimental data? What type of experimental data is important? Can I do away with experimental data as you said that I'm going to rely on sensitivity analysis. Is it good enough?

So we are learning a lot of stuff. But right now, we have to put everything together. And this is what we are planning to do in the next year or so. And see how this system works. What is the source term? You know, what is going to -- you know, what are the clippage effects as I mentioned before?

MS. CUBBAGE: I wanted to just add one point. We've heard loud and clear from the committee in previous meetings on the LMP citing the PRA discussions yesterday that there's concern about do applicants do know how to do source term? Does there need to be source term guidance? So one of the duel-purposes of this exercise and why NRO is sponsoring it is you know, we are using tax payer dollars for this. We're going to use publically available information on the designs, rather than a proprietary design. And we're going to make information publically available.

Have workshops so that we can explain to developers how we've exercised MELCOR because we do understand that many developers do plan to use MELCOR or similar tools.

MEMBER REMPE: So that was the -- I'm glad you said you were going to have workshops because I have a lot of interactions with them as you go along. And so if they bring up a valid point. Oh, we're not considering this. This is a good way to influence this. But I think this is a good approach and I'm glad to hear about it.

MR. ESMAILI: So I didn't want to go into a lot of details. As I said, yes, we're going to do this. We're going to have workshops for NRC staff. And then we're going to go public to say this how we are doing things. This is what we think is happening. And this is how probably -- how we are going to review whatever is coming.

MEMBER MARCH-LEUBA: How confident are you of MELCOR probabilities for molten salt? I'm thinking fission product retention. Do we even have experimental data for that?

MR. ESMAILI: When you start talking about molten salt, you're talking about like FHR type of --

MEMBER MARCH-LEUBA: When you have molten salt, if you release it from TRISO or from inside itself, you are going to have retention of most of the fission products.

MR. ESMAILI: So if it comes out of the -- If it's a pebble bed, you know, just like a pebble bed and they have TRISO, we are exercising the same model.

(Simultaneous speaking)

MEMBER MARCH-LEUBA: But do you have the fundamental data to know that silver doesn't get retained, but iodine does?

MR. ESMAILI: This is something that we are working on. This is something that we have stressed -- you know, we are working with DOE to have the information and you know, the specificity, et cetera.

MEMBER MARCH-LEUBA: To you, you are much more simplified example. Can we get a beautiful 3D neutronics model versus point kinetic. But if I don't know what better effective is, I cannot do the calculation. Same thing, you can have a beautiful MELCOR model, but if you don't know how much iodine the molten salt retains, you cannot do the calculation.

MR. ESMAILI: Yes. And those are some of the unknowns. We know the basic framework of the model. What we don't have is the data of what's put into the model. For example, when HTGRs set up, I have this diffusion equation, but I don't have the statistical information that goes in and says how things are diffused. But these are some of the things that we can give -- So we are doing all of these things in peril. We are developing the models. We're putting into the code. We're doing full front calculation. And at the same time, do require data. I think this is the same data that I think that the vendors or whoever is going to -- they would need too. So in LWRs, they're sharing the same data. We are not going with one independent, you know, experimental assessment.

MEMBER PETTI: Are you aware there's some new data coming out on salt -- fission product release from salts by the Canadians?

MR. ESMAILI: Yes. And I mean I don't know if they published it yet.

MEMBER PETTI: I don't think they have.

MR. ESMAILI: Are you guys all linked in with the GAIN workshops or the technologies? That's probably how you can keep your finger on the policy.

MR. BAJOREK: Yeah, I think there's -- I think there's a couple of NEUP studies going on right now that are also sort of addressing that. But that's a phenomena that we don't have a lot of data for yet. But we know everything's working.

MEMBER PETTI: Well what I hear is that the results do not -- are not showing ideal behavior.

MR. BAJOREK: Yes.

MEMBER PETTI: Which means greater release than thermodynamic --

(Simultaneous speaking)

MR. ESMAILI: That is why we need to have these codes ready. Because I was actually at CNL, you know, last year and Mike Salay -- he's a colleague of mine. He's involved in the PIRT. So we are aware of those experiments that show potential releases. And they are interested in the same thing. So we are also interested. But I think what I'm saying is that we are working on the basic models. Because we don't think the basic modeling is going to change. It's just that what are the clippage? What is the temperature at which you expect this enhanced release, et cetera?

PARTICIPANT: We're trapping.

MEMBER PETTI: Yeah. You need the constitutive --

(Simultaneous speaking)

MR. ESMALI: That's right and that's why we need the data, correct. So that's why I said that, you know, it goes three years. You know, we're still working on this. But this is providing some additional information.

MR. LEE: This is Richard Lee from Research. Dave, we have access to the CNL information through the CSAC program. But I think the temperature they run is very high. I told them that they need to conduct additional tests to come down in temperature for the releases.

MR. ESMAILI: Yeah, this was not a very comprehensive experiment. It was very, very small scale. They had these little bowls, et cetera that they mixed the fuel. So we have to understand. And right now, I don't want to make it, you know, one way or another.

MR. LEE: But it's the first data that I've seen on this stuff.

MR. ESMAILI: The first data, yes. Yes.

MR. LEE: So at least they're thinking in the right direction.

MR. ESMAILI: Yeah.

MS. WEBBER: I think Steve has two more slides.

MR. ESMAILI: I'm done.

MR. BAJOREK: Okay, what I'd like to do now is -- This is Steve Bajorek again. What I'd like to do now is just sort of wrap up and talk about just some overall summary and conclusions as we see it. And talk about some of the next steps that we're going to be doing.

Right now, we see Volumes 1 through 3 of the Strategy 2. They document the codes, the outline the analytical approach that we would use for independent NRC analysis. We think it covers all of the different design technologies that we're going to have to face. There are uncertainties in you know, constituent of models. And we know that assessment needs to be done. Using the codes and the models right now, at least starts to help to develop the staff expertise and understand how these new designs should really operate.

We've spent a lot of our time in developing Volumes 1 through 3 and trying to identify the technical gaps in terms of modeling, experimentation, assessment. We're working right now with Department of Energy to identify some of those experimental data needs which are missing and need to be refined.

We do reserve the right to become smarter as times goes on. As the designs mature and they come in with new information, we may identify some additional gaps that need to be resolved. So this is based on what the applicants have told us right now. A lot of the public information that's out there for these various types of designs.

The scope and the depth of the analysis that we would do is going to depend largely on what the application is, the review strategy that the applicant wants to pursue, ideas on the safety margin, power level, burn-up, initial fission product inventory, and the needs of the User Offices. So those --

MEMBER BLEY: I'm not sure what you mean by the review strategy the applicant chooses to pursue.

MR. BAJOREK: Whether it is more --

(Simultaneous speaking)

MR. BAJOREK: Well they can come into our Part 50, Part 52.

MEMBER BLEY: Oh, okay. If that's what you mean --

MR. BAJOREK: I believe they can use the LMP --

MEMBER BLEY: -- I understand.

MR. BAJOREK: -- can be more deterministic. We can't say we're marching down one path. We need to hear from them.

Next steps, we're going to revise each of the documents based on what we've heard from the subcommittee, the full committee, your letter, and from other stakeholders who are involved with -- we've met with. We've met with some of the technology working groups. We've met with stakeholders on a periodic basis. And we have comments from them.

We would hope for each of these volumes to come out with a Rev 1, maybe the end of the year. That's going to depend on resource and personnel availability. The one that needs the most work is the introduction. This was put together rapidly towards the end of getting Volumes 1 through 3 before the May 1st meeting. And it needs to better articulate what's our anticipated use of the analysis codes in the review and with the LMP? How do we sort of see these fitting? We want to emphasize that our approach is to one, right now remain flexible. Simplify our review to the extent possible and right-size it to the analytical -- right-size that analytical approach to the needs of what that application really entails.

Finally, we need to point out that these codes, the analysis that we do, they educate us. They help us inform ourselves on how the machine should work. What we should focus on in the review. Ask intelligent questions of the applicant when they come in. But they're not going to be the analysis of record. Now that doesn't mean that hey, we cannot assess them and we just take whatever results. Yes, we realize that we have to do an amount of assessment -- amount of V&V that puts us at least on the level playing field as the applicant. So we intend to do that. But at the end of the day, it's the applicant's analysis that will become the analysis of record.

We'll be working on Chapters 4 and 5 on dose assessment and fuel cycle related topics. I don't have a date for you when I think those are going to be complete. In the meantime, we're going to continue to work on these full plant models and exercise what I call the reference plans. We'll put things together that we think look and behave much like the applications plan is going to be. But we'll base it on publically available information.

The megapower for the microreactor that we're running right now, it looks very much like one of the applications. We have another microreactor model that we anticipate being able to start using in December. It looks like another one of the applications. And this is what we'll use to try to find out what are -- first of all, we try to run it and from a code developer's point of view, I want people to take it and break it. Okay? I want to know what are the weak parts of this model, so we can improve that now before the application in. But start doing sensitivities to see what really has a big impact on the results? So we either can refine those models, refine our methodology, or improve the constituent of models in order to do a better job on the calculation.

We're both working on these Volume 1, 3, and I think 2 with the stand alone models for the fuel elements, which I hope to see in the near term. So we can one, investigate how the codes run. Make sure they're running on our computational platforms. We're doing that right now with the microreactor to see if there's any glitches. And be prepared so that when the application comes in, we're able to take those reference models, complete the assessment, and then modify them to look like the applicants design so we can go ahead and accommodate the User Offices as part of the review.

But first I'd like to thank everyone's questions and comments on this. It's been brought up, some of this is confusing. It probably should be because these designs are new to, I think, everyone. And anything you could point out in the direction of new data and where we should go with these is very desirable. Thank you very much.

MS. WEBBER: And this is Kim Webber. I also want to echo the thanks. Because I think even since we had the meetings with DOE, our thought processes have evolved with our interactions with you. And so I really appreciate the interactions, the comments, the letter. And I think at the end of this, you know, we're going to take the information that we have from your letter and include that when we revise the introduction in all parts quite frankly. So thank you. I appreciate your time and dedication to doing this for us.

MEMBER BLEY: Okay. Well thank you, the staff for really good discussions here and during the subcommittee meeting. Before I turn it back to the chairman, I should ask for public comments? Can we get the phone line open? Is there anyone in the room who would like to make a comment? If so, please step up to the microphone and identify yourself. Do we know if the phone line's open? Could somebody go over and check and make sure they have it open?

Is there anybody on the phone line? Please speak up and let us --

PARTICIPANT: It's open. This is Matt. The line's open.

MEMBER BLEY: Thank you. Hi, Matt. Okay, is there anyone on the phone line who would like to make a comment? Again if so, please state your name and give us your comment. Okay. With that, Mr. Chairman, back to you, a full three minutes late and my apologies.

CHAIRMAN RICCARDELLA: It's good because we have another topic starting at 10:15. And --

MEMBER REMPE: Is the NuScale session going to be transcribed? It is going to be transcribed.

CHAIRMAN RICCARDELLA: And is it open?

MEMBER REMPE: It's open.

CHAIRMAN RICCARDELLA: Okay. Okay, so with that, we will recess until 10:15.

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

Advanced Reactor Computer Codes

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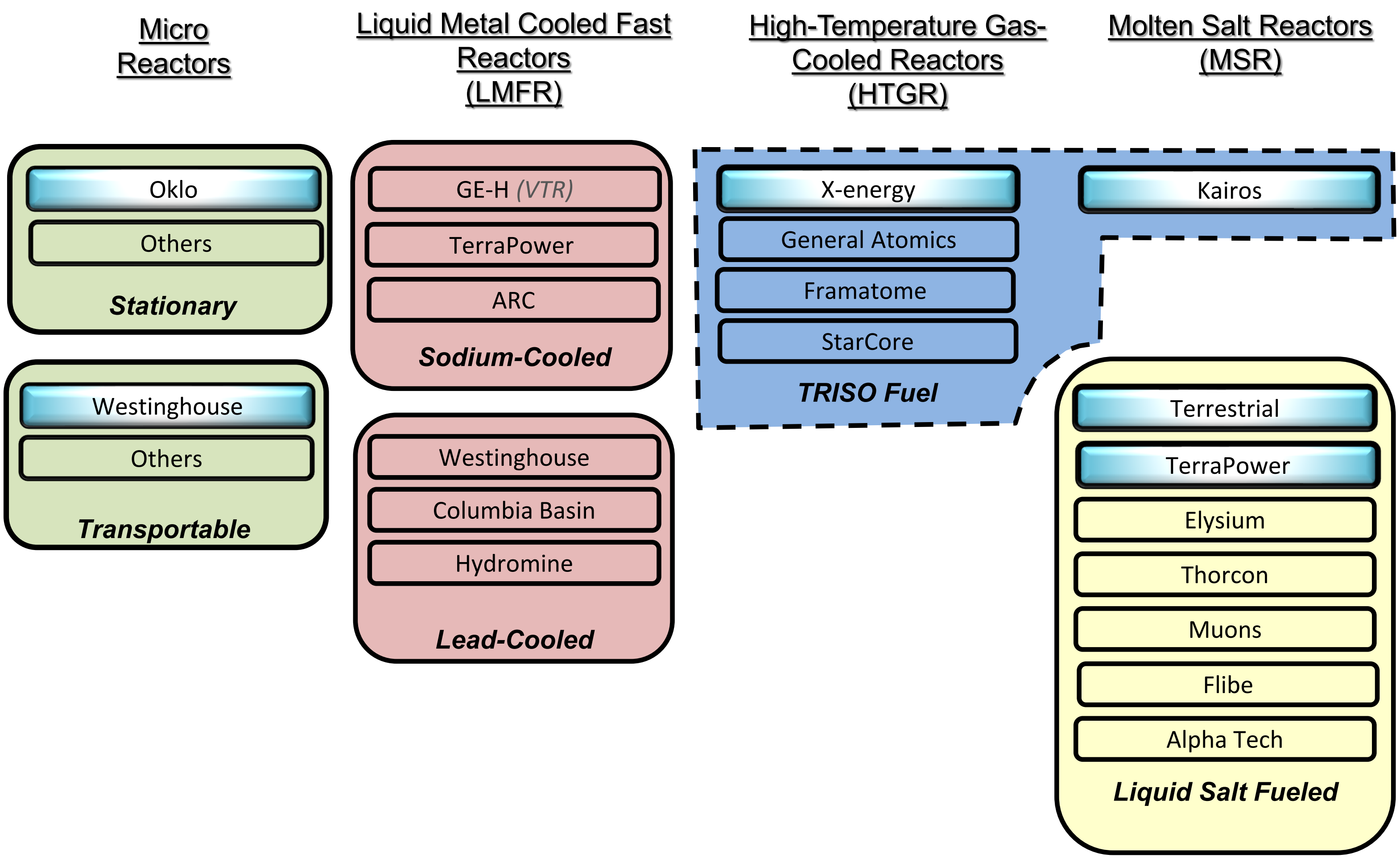
Advisory Committee on Reactor Safeguards Meeting
October 3, 2019

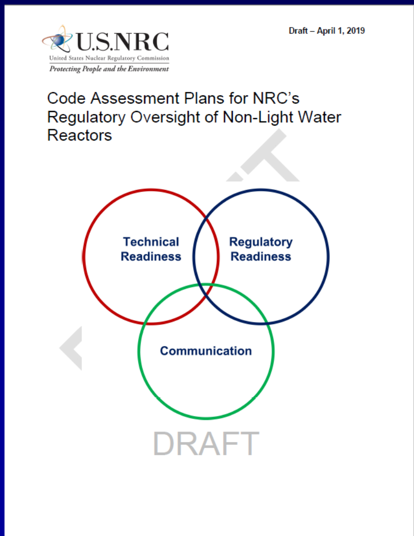
Introduction

- "Strategy 2" of the Implementation Action Plan (IAP) is directed at identification & development of computer codes and tools to prepare the staff for evaluation of advanced non-LWRs.
- Objective of the IAP "Strategy 2" is *readiness*.
  - All plant designs considered equally likely for DC.
  - Licensing approach may, or may not, use LMP.
  - Near-term submittals & shorter review schedules expected.
- Many advanced designs are under development and the "landscape" continues to evolve.

Advanced Reactor Landscape



Strategy 2 – Computer Code Reports



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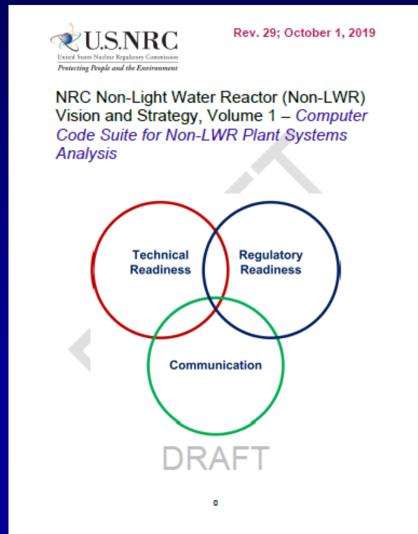
Introduction



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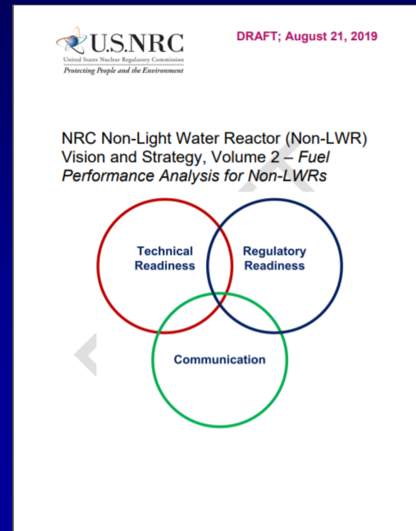
Volume 1



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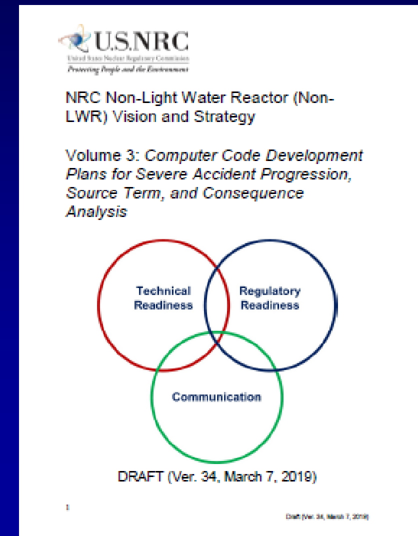
Volume 2



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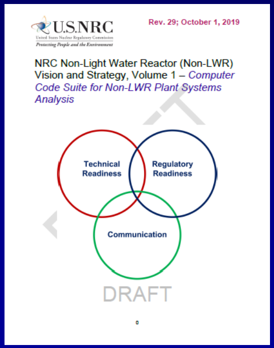
Volume 3

Volume 4 = Licensing and Siting Dose Assessment
Volume 5 = Fuel Cycle Topics

Under Development

These Volumes outline the <u>specific analytical tools</u> to enable independent analysis of non-LWRs, <u>technical "gaps"</u> in capabilities, <u>V&V needs</u>. Gaps in experimental data is currently being identified.

Range of Capabilities in Vol. 1-3

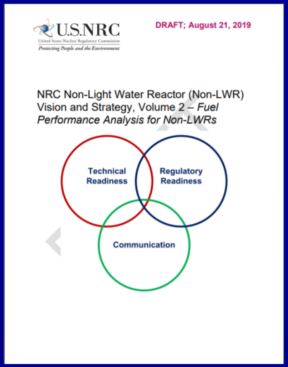

U.S.NRC
Rev. 29; October 1, 2019
NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy, Volume 1 – *Computer Code Suite for Non-LWR Plant Systems Analysis*

DRAFT

Volume 1

- Are safety functions/systems adequate?
- Are the operating limits acceptable?
- Are the ARDC satisfied?
- How does the machine work?

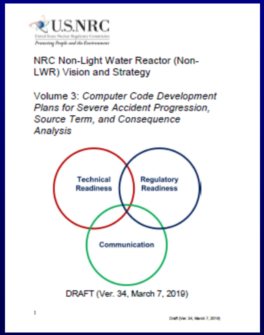
Initial Conditions
Material Properties
Failure Mechanisms


U.S.NRC
DRAFT; August 21, 2019
NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy, Volume 2 – *Fuel Performance Analysis for Non-LWRs*

Volume 2

Initial Conditions
Material Properties
Failure Mechanisms

Volume 3


U.S.NRC
NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy
Volume 3: *Computer Code Development Plans for Severe Accident Progression, Source Term, and Consequence Analysis*

DRAFT (Ver. 34, March 7, 2019)

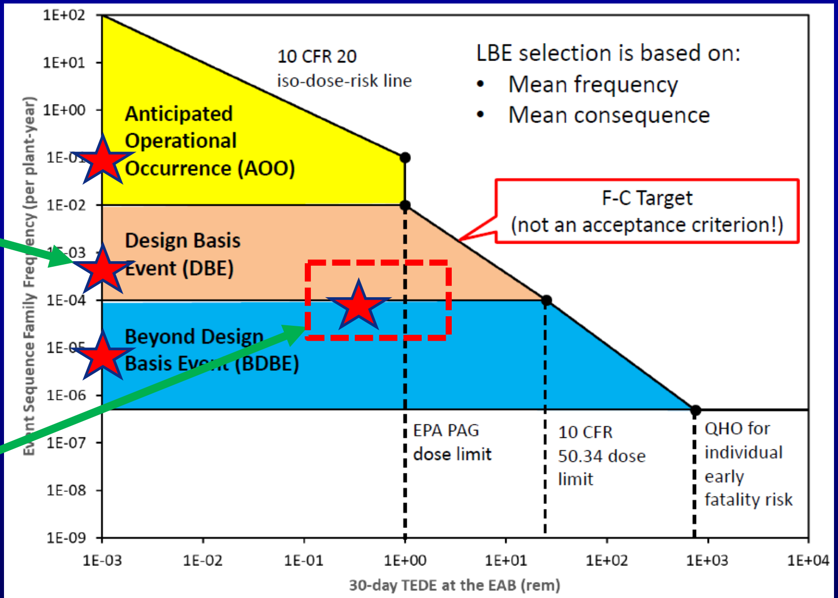
- What is the fission product inventory?
- What is the Source Term?
- Where can the fission products go?

Role of NRC Codes with non-LWRs . . .

- Remains to be defined and will be based on applicant submittals, perceived safety margin and User Office needs.
- Recent LMP pilot studies provide insight on potential review questions.

"Y-axis case": No FP release, questions to involve adequacy of safety systems, verification of safety margin claims.

"Non-zero dose": Source term, with questions to involve FP transport, event frequency & their uncertainties.



Independent analysis with NRC codes develops staff understanding & expertise.

Volume 1

Computer Code Suite for Non-LWR Plant Systems Analysis

Volume 1

- "BlueCRAB" represents an integrated code suite for nuclear plant systems analysis. It is a combination of NRC codes and limited number of NEAMS based codes.

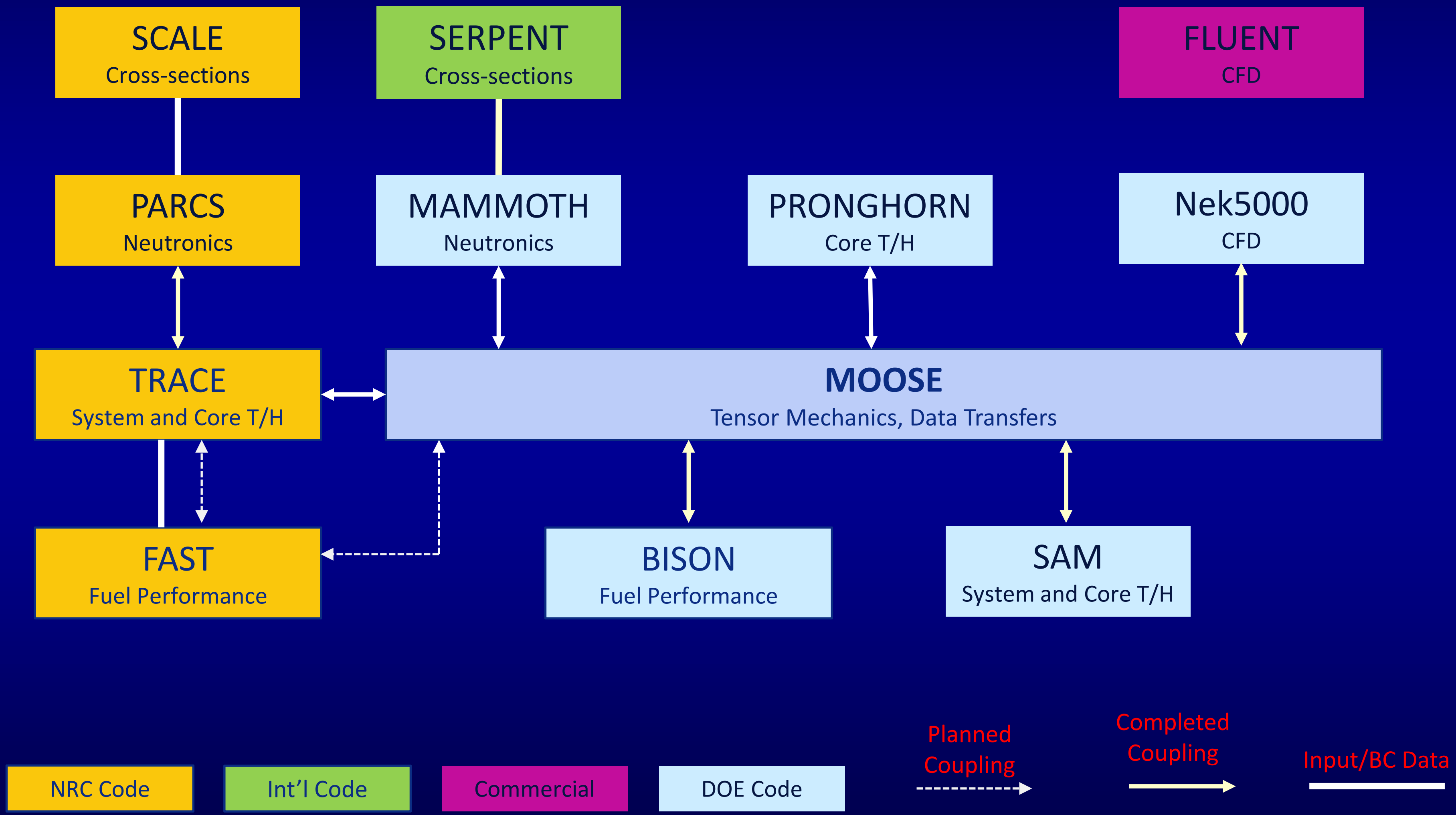
- Technical "gaps" are outlined and are based on review of available PIRTs. V&V requirements are also specified.

- Flexibility: "BlueCRAB" is applicable to all of the expected applications – however not all codes are used for a particular design type. (See microreactor example on following slides.)

- Complexity: We do not expect to develop high resolution models, or utilize detail where not needed. KISS – and then add detail as the regulatory issue or technical concern demands.

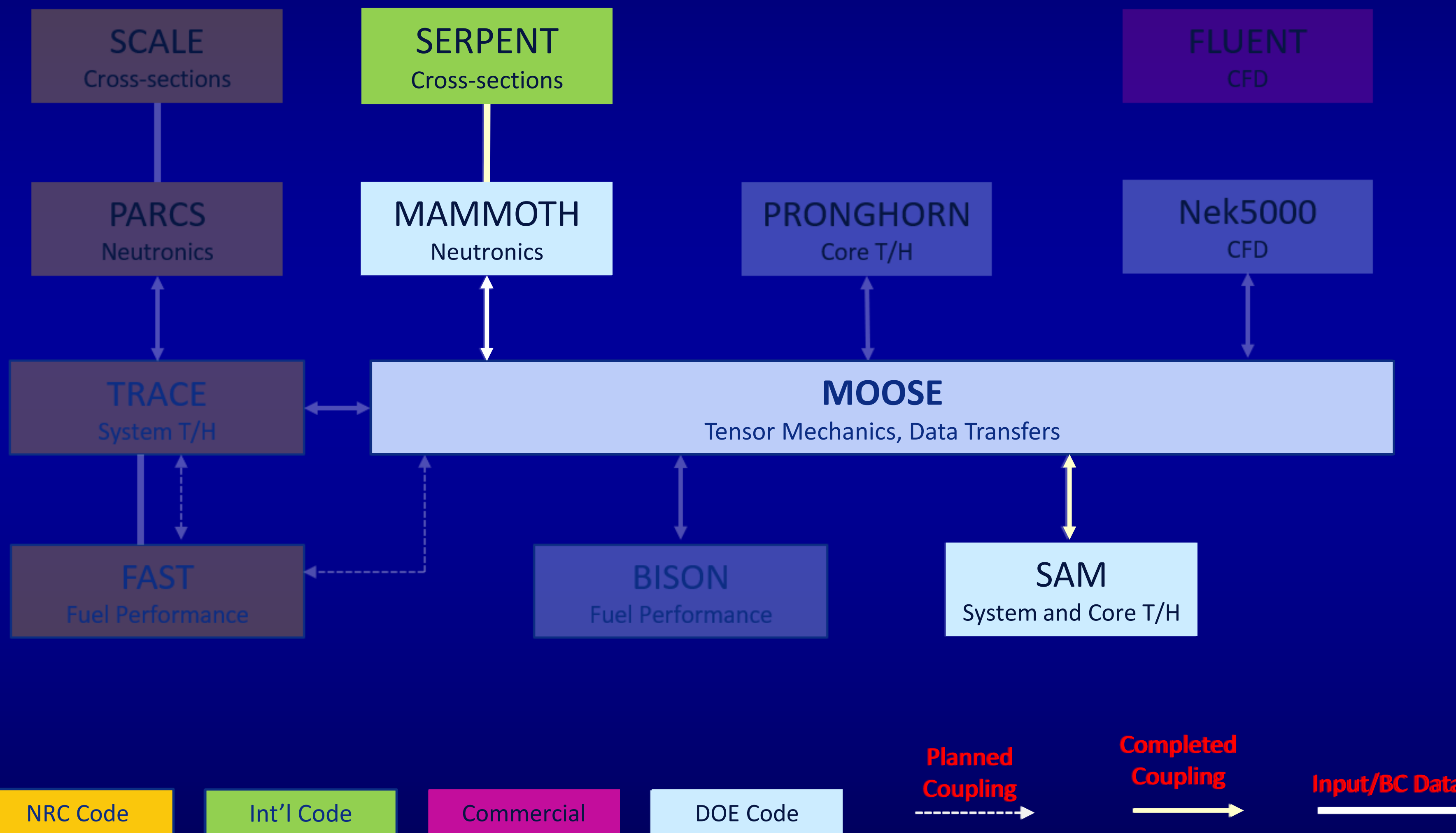
Comprehensive Reactor Analysis Bundle

“BlueCRAB”



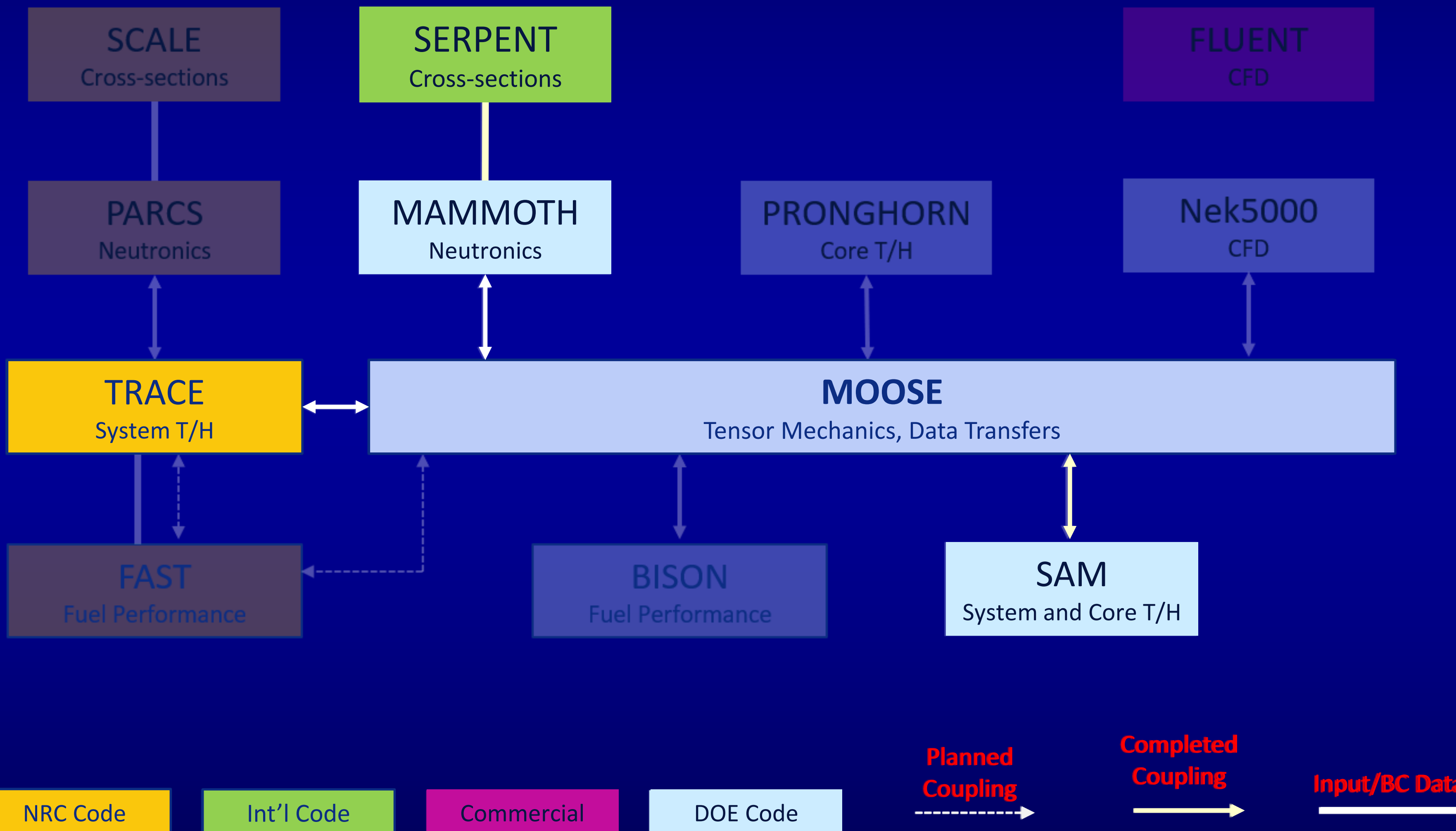
Comprehensive Reactor Analysis Bundle

BlueCRAB - MicroReactor



Comprehensive Reactor Analysis Bundle

BlueCRAB – MicroReactor w/RCCS



Current View; Sept. 2019

Volume 2

Fuel Performance Analysis for Non-LWRs

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

NRC non-LWR Computer Code Development Plans for Fuel Performance

Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

October 3, 2019

Fuel Review Methodology

- Reg. Guide 1.232 proposes Advanced Reactor Design Criteria for non-LWRs
  - Vendors may adopt ARDC or develop their own plant-specific design criteria
- NRC fuel reviews verify compliance with fuel-related design criteria
  - E.g., no fuel failure during normal operations and AOOs, ability to shut down reactor always maintained
- Fuel performance codes often used to aid fuel design reviews

Supporting Fuel Design Reviews

- Planned approach for using FAST will be similar to approach for LWRs
  - Perform single-fuel-element standalone calculations to verify fuel safety limits are met
  - Perform full-core analysis in conjunction with neutronic and thermal hydraulic tools
- FAST interfaces with other codes may be manual (current approach for LWRs) or direct code-to-code coupling
- Current focus is on metallic and TRISO fuels
  - We will re-prioritize as new information becomes available

FAST Status

- FAST is currently under active development for non-LWR fuels
  - Significant progress made on metallic fuels
  - TRISO fuel models less developed, but will be ready to support licensing activities
- Most data needs expected to be met by existing database (metallic fuel) and by planned DOE programs (AGR)
- NRC staff is also maintaining awareness of BISON and its capabilities

Volume 3

Plans for Severe Accident Progression, Source Term, and Consequence Analysis

NRC non-LWR COMPUTER CODE DEVELOPMENT PLANS FOR SEVERE ACCIDENT PROGRESSION, SOURCE TERM, AND CONSEQUENCE ANALYSIS

Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

October 3, 2019

Regulatory Source Term

- Accident source term
  - Release of radioactive materials into the containment or the environment
  - Used for siting, EPZ sizing, control room habitability, and equipment qualification
- Estimate risk-informed source term
  - Use best estimate computer codes
  - Phenomenology (e.g., radionuclide release from fuel, aerosol dynamics)
  - Experimental assessment
  - Selection of accident scenarios

Evaluation Model

- Leveraging decades of physics model development and validation that can be extended to non-LWRs
  - Most efficient approach to support confirmatory analysis using NRC developed computer codes SCALE/MELCOR/MACCS
  - For some technologies (e.g., HTGR), the models are ready to be tested
- Technical approach and basic framework
  - Similar to LWRs
  - SCALE reactor physics analysis provides necessary input (e.g., fission product inventory and decay heat) to MELCOR and MACCS
  - MELCOR accident progression analysis predicts fission product release from the fuel and release to the environment (source term input to MACCS)
  - MACCS predicts dose, health effects, and economic/societal consequences
  - Vol. 3 report (ML9093B404) provides a detailed development plan
    - Selection criteria (e.g., staff familiarity, domestic and international use, and life cycle development and maintenance costs)
    - Existing capabilities and modeling gaps (using PIRTs)
    - Data needs (modeling parameters and validation basis)

Code Development

- Code Attributes
  - Technology-inclusive (LWR, HTGR, SFR, MSR, FHR, HPR)
    - Best-estimate & State of the Art - Reflects current scientific knowledge supported by experimental observations
    - Integral - provides feedback among phenomenological models
- Current Focus
  - Full plant demonstration calculations – involves development of input models and running simulations. Sensitivity calculations can provide insights on the role of modeling parameters and systems interactions.
  - Data transfer and interface between SCALE & MELCOR
    - MELCOR/MACCS interface is an existing capability
  - Near-field atmospheric transport

Summary & Conclusions

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- Volumes 1 - 3 of the IAP "Strategy 2" document the codes intended for independent NRC analysis of non-LWRs in support of licensing reviews. Use of these codes also develop staff expertise.
- Technical "gaps"; modeling needs and capabilities, necessary V&V, experimental data are outlined in the reports. Additional gaps may be identified as new design information becomes available.
- Scope and depth of the independent analysis using these tools is TBD, and will depend on the application, perceived safety margin, and needs of the User Office(s).

Next Steps . . .

- "Strategy 2" documents (Introduction, Volumes 1-3) to be revised based on ACRS and Stakeholder comments. "Rev. 1" of each Volume expected by end of year.
- "Introduction" revision to better articulate . . .
  - Anticipated use of analysis codes with LMP
  - Flexibility & simplicity to "right-size" the analytical approach
  - NRC codes and analysis are to educate staff and inform the review, and are not the analysis of record.
- Complete Chapters 4 (Licensing and Siting Dose Assessment) and 5 (Fuel Cycle Related Topics).
- Develop & exercise reference plants for non-LWRs for early insights.