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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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691ST MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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WEDNESDAY

DECEMBER 1, 2021

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OPEN SESSION

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 8:30 a.m., Matthew W. Sunseri, Chairman, presiding.

COMMITTEE MEMBERS:

MATTHEW W. SUNSERI, Chairman

JOY L. REMPE, Vice Chairman

RONALD G. BALLINGER, Member

VICKI M. BIER, Member

DENNIS BLEY, Member

CHARLES H. BROWN, JR., Member

GREGORY H. HALNON, Member

VESNA B. DIMITRIJEVIC, Member*

DAVID PETTI, Member

ACRS CONSULTANT:

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

ZENA ABDULLAHI

*Present via teleconference

CONTENTS

P R O C E E D I N G S

8:34 a.m.

CHAIRMAN SUNSERI: The meeting will now come to order.

This is the second day of the 691st meeting of the Advisory Committee on Reactor Safeguards. I'm Matthew Sunseri, the Chair of the ACRS.

Members in attendance are Dave Petti, Ron Ballinger, Greg Halnon, Vicki Bier, Joy Rempe, Walt Kirchner, Dennis Bley.

Let me ask, is Vesna Dimitrijevic on the line yet?

(No response.)

We expect Vesna to be joining remotely.

And Steve Schultz, our consultant, is also in the room with us.

There is an accident out on the highway that's preventing some members from getting here. Charles Brown will be here as soon as he is safely able to do so, and Scott Moore, our Executive Director, and Elisha Ballinger (phonetic) are also in traffic trying to get here.

The Designated Federal Officer for this meeting is Ms. Zena Abdullahi.

During today's meeting, the Committee will consider the following:

The first topic is the Research Information Letter on Fuel Fragmentation, Relocation, and Dispersal During LOCA. This will be a presentation followed by report preparation by the Committee.

Secondly, we will continue with the report preparation on Draft Guide 5061, which deals with Cyber Security.

A phone bridge line has been opened to allow members of the public to listen in on the presentations and Committee discussions. We have received no written comments or requests to make oral statements from members of the public regarding today's session.

There will be an opportunity for public comment. We have set aside time in the agenda for comments from members of the public attending or listening to our meetings. Written comments may also be forwarded to Ms. Zena Abdullahi, the Designated Federal Officer.

A transcript of the open portion of the meeting is being kept. It is requested that speakers identify themselves and speak with sufficient clarity

and volume, so they can be readily heard. Additionally, participants should mute themselves when not speaking.

And just as a note to our agenda topic, Research Biennial Review is schedule for 1:00 to 2:30 today, but that topic has been taken off the agenda because we completed that work at our last full Committee meeting. So, we will redirect that time allotted for that topic to report preparation.

All right. This is the second day of our use of what we'll call hybrid meeting format. And yesterday was really, really a good experience. I think we had a very good meeting. We effectively demonstrated how to use this technology, but we did learn some things. So, let me just cover a couple of highlights from yesterday.

First off, for the speakers around the table here, it is very difficult to hear you talk in the room. Ironically, if you're outside of this room, you're crystal clear. All right?

(Laughter.)

So, what we're going to ask you to do -- and we're working on the issue; in fact, there will be some technicians behind the scenes trying to adjust the gain on these microphones today. They need the

full room in place to do that and the dynamics. It's a balancing act between these mics and the feedback of the main system. So, we do acknowledge that problem. We do acknowledge that it's being worked on, and we appreciate your patience as we work through that.

However, what I'm going to ask you to do as the speakers around the table, to not only use your mic here, but use your playground voices if you're talking to the other kids out on the playground to help us hear you until we get this fixed. All right?

The second thing is, I had asked all participants in the room and remotely to provide feedback to us, and I did get some feedback yesterday from remote presenters that said, you know, they were getting static or sounds of people not muting their microphones, or whatever. And as it turns out, that's a problem with the room microphone setup. They're shuffling the papers or people are getting up and moving around. These speakers are very sensitive and may pick that up, and it's a distraction to the people speaking remotely.

So, I'm going to be aware of that, and if I see jostling in here, I can mute the system and cut that out. We will still be able to hear them, but they won't be able to hear us.

But what I'm going to ask you to do is let's try to minimize that distraction. And, also, as a reminder, since the speakers are on all the time, when you see this green light on, anything, any background noise, any sidebar conversations are being picked up. All right. So, just be aware that there is an open mic as long as this green light up here is on. All right?

So, I think that is it. Anybody else have anything they want to share as far as lessons learned from yesterday's hybrid?

We did fix the lights in the room.

MEMBER BLEY: Kudos to all who made that happen. There was a temporary fix yesterday, but until Maintenance comes back and puts the bulbs in, we should be okay.

CHAIRMAN SUNSERI: Yes, our great staff did a wonderful job of responding.

One last thing, you'll note in the room up here there's this display over the main console that says, "Open Right Now." That's a designation of what type of meeting we are in. So, we are in an open session right now. When we go to closed session, that will be change to "Closed." All right? And the alternation between the session and the time, if you

don't like the alternating, we can stop the time and we can adjust that display. But I think it's fine the way it is.

All right. Anything else?

(No response.)

Thank you. We will now get started with the first topic, and I'll turn to Member Ron Ballinger for opening remarks or introductions of the Research Information Letter topic.

MEMBER BALLINGER: Thank you, Mr. Chairman.

Today's meeting will be a summary, I believe -- actually, an expanded summary in some cases -- of the Subcommittee meeting that we had on November the 17th, at which point we had a fairly spirited discussion of the topic and we had some spirited comments from stakeholders; namely, NEI.

So, today's presentation, we will have a presentation from the staff first, and then, NEI has asked for time for a presentation. So, they will give a presentation after the staff.

And so, with that, I think, is it Michelle?

VICE CHAIRMAN REMPE: Ron, if you don't mind, I need to interrupt for just a minute?

MEMBER BALLINGER: You can interrupt, anything you want.

VICE CHAIRMAN REMPE: Oh, you're so kind.

Okay. I need to just state that I'm going to have to limit my participation in some of this discussion because of what might be perceived as a conflict of interest on this topic. And I need to put that on the record, and thank you.

MEMBER BALLINGER: And I add that's not an advantage.

(Laughter.)

So, who is going to do the presentation? Okay, Kim, the floor is yours.

MS. WEBBER: Okay. Good morning, Chair Sunseri and Subcommittee Chair Ballinger. It's a real pleasure to be in this room with you today rather than in a separate or at our homes, in the offices. So, I'm glad that we're part of the inaugural ACRS meetings back in this room. It's really a great chance to see all of you in person.

MEMBER BALLINGER: Yes, but I don't know what kind of an advantage that is.

(Laughter.)

MS. WEBBER: My name is Kim Webber. I'm the Director of the Division of Systems Analysis in

the Office of Nuclear Regulatory Research.

On November 17, the staff briefed the Metallurgy and Reactor Fuel Subcommittee on the Research Information Letter, or FIL, related to Fuel Fragmentation, Relocation, and Dispersal, or FFRD. We are pleased to brief the rest of the ACRS members today on this important topic.

As you know, industry is very interested in pursuing licensing of current fuel designs to higher burnups. Under conditions described in the RIL which include high burnup, FFRD has been observed. And understanding of the mechanisms that lead to FFRD represents one part of a larger analysis to evaluate the safety of reactor operations using high burnup fuel.

As you know, an assessment of the thermohydraulic behavior of the reactor coolant under loss of coolant accident, or LOCA, conditions and the consequences of any potential fuel dispersal following a LOCA are two other really important parts of the safety analysis.

The purpose of the RIL is to document and communicate to NRR the research that exists to date on the mechanisms of FFRD, and it provides insights regarding the basis for the empirical limits. It does

not include a LOCA analysis or an assessment of the consequence of the potential for fuel dispersal into the coolant.

In the past, RILs have been used to support the development of regulatory guidance. In this case, the determination to develop that regulatory guidance, or any guidance associated with high burnup or FFRD, lies with NRR. My staff have been working very close with their NRR counterparts, and we do have staff from NRR in the audience today. So, they've discussed the body of research that is currently available, and they continue to monitor the research activities, and through their involvement in many of the different international programs involving high burnup.

So, unless there's any questions, I'd like to turn the presentation over to Michelle Bales.

MS. BALES: Thank you, Kim.

My name is Michelle Bales. I work in the Office of Research, and I will be presenting, along with my colleague Lucas Kyriazidis, the Research Information Letter 2113.

Next slide.

CHAIRMAN SUNSERI: Yes, and if you could bring this (referring to the microphone) as close to

you.

MS. BALES: Okay.

CHAIRMAN SUNSERI: It's got a little bit of a cord. You can bring it a little closer.

MS. BALES: Is that better?

CHAIRMAN SUNSERI: Yes.

MS. BALES: Okay.

CHAIRMAN SUNSERI: But turn it on.

(Laughter.)

MS. BALES: Oh, man, this thing is very sensitive.

CHAIRMAN SUNSERI: It's sensitive.

MS. BALES: Can you touch anywhere to --

CHAIRMAN SUNSERI: The green light, or red light.

MS. BALES: There.

CHAIRMAN SUNSERI: There. Thank you.

MS. BALES: Hopefully, that will be the biggest stumbling block here.

CHAIRMAN SUNSERI: Hopefully, yes.

(Laughter.)

MS. BALES: Okay. So, the presentation today will start with history of FFRD. I'll go into programs that are cited in the RIL, as well as the peer review process that we used. I'll speak to the

outcome of the RIL; in other words, how the RIL could be used, and then, dive into the basis for the empirical limits, and then, finish with some other matters.

So, first, the history.

I actually want to warn Kim there is a lot of animation here. So, I might be telling you to click again.

MS. WEBBER: Yes.

MS. BALES: So, this is the slide, correct?

Our Research Information Letters have been used for a variety of purposes. I want to spend just one minute explaining why we chose a Research Information Letter for this set of information.

They're a tool, and as our public website explains, they are a tool that is used for internal communication from the Office of Research to a licensing office to provide a concise summary that makes it easier for the regulatory offices to process and utilize complex information. That seemed to fit the mold in this case.

If you would go to click one more time?

In addition, in the fuels area, RILS have been used a couple of times. First, in 2004, there

was a RIL written to summarize a large body of research relating to reactivity-initiated accidents. And then, in 2008, there was a RIL written for the large radio research on cladding embrittlement under LOCA conditions. In both cases, guidance for proposed rulemaking followed.

And if you click one more time? Right.

The RIL, as I said, there's a lot of information that is summarized in the RIL. It's broad in scope. It's difficult to understand the experiments on their face value, and it would be very time-consuming to digest all of it. So, all of the images sort of just represent the complexity of the information that is presented.

And one more click.

MEMBER HALNON: Michelle, why not a NUREG or something to that effect that is a report and a process more attuned to passing complex information?

MS. BALES: I think a NUREG certainly would have been an acceptable choice. A Research Information Letter is a particular tool to communicate the regulatory context to a program office or to a licensing office. So, it seemed to fit in this case.

They've been used for a variety of applications the same way NUREGs have. To be honest,

I think some of it came from the fact that they have been used in the fuels area in the past, as I mentioned, in 2004 and 2008.

MEMBER BALLINGER: For one reason or another, I don't have this presentation. Does everybody else have it?

MS. BALES: There are three new slides relative to the Subcommittee presentation. So, this is one of them. During the Subcommittee discussion, there were some questions, I think, about what a RIL was and why it was chosen. So, I added this slide to help that discussion.

MEMBER BALLINGER: Can we make sure that Zena gets a copy of this?

MS. BALES: Absolutely, yes.

MEMBER BALLINGER: And I have a question. Normally, Research does work in response to a user need.

MS. BALES: Uh-hum.

MEMBER BALLINGER: And I've asked for the user need, but we haven't got it. Is there a user need for this? And if there is one, can we get it?

MS. BALES: Okay. So, Research often does work in response to user needs, but it's not the only occasion that research is conducted. In the case of

the information that's contained in the RIL, the SCIP, Cladding Integrity Program, for example, it is not mentioned in a user need. We participated in that program, that international joint project, as part of the research -- what do you call it? I guess it's just a research plan, but it's, in general, the Office of Research participates in a lot of international programs outside of specific user need requests.

Having said that, as we got further along, and particularly, in preparation for high burnup applications, there was a user need created for high burnup issues specifically, and the RIL was mentioned as a tool to support that effort. And so, there is a user need that we can provide which identifies the Research Information Letter.

MEMBER BALLINGER: That would be great.

MS. BALES: I just want to say that the body of work that it refers to itself is not any user need. Our participation in this program was a commitment that Research made outside of that.

MEMBER HALNON: But is the RIL a public document?

MS. BALES: Yes, RILS are public documents.

MEMBER HALNON: Okay. Real time? I mean,

I guess what I'm asking is, is it issued, and then, the industry gets it real time, as opposed to a year or two down the road after it's digested by the NRR?

MS. BALES: So, right now, a copy of the Research Information Letter is available in draft to support this meeting, because it's a public meeting and all of the materials for ACRS meetings are public. Once it's signed and concurred on, and transmitted officially from the Office of Research to NRR, it is public that moment. There's no digestion period from the program office.

MEMBER HALNON: So, when it gets through the process?

MEMBER BLEY: I think you can also get a RIL out much quicker than a NUREG, I believe. And there was something of a sense of urgency in getting this out, I think, from what you talked about at Subcommittee.

MS. BALES: Yes, there's high burnup applications that are coming in through the licensing office right now. And we wanted to put information in the staff's hands that would allow them to review that information in the context of what we know about these phenomenon. And so, we wanted to make that available as soon as possible.

MEMBER BLEY: And I'm going to say this a little wrong, but it strikes me from what I heard at this Subcommittee there's a lot of knowledge gaps remaining here. And I guess having this in the hands of NRR is important, so that they know what went on and what we don't know before they have to decide on an application.

MS. BALES: Yes.

MEMBER BLEY: I mean, I assume that's what's driving that.

MS. BALES: Yes, and I also want to say that this is all public information. So, there could be proprietary information that would supplement this, and it could appear in a license application. So, even the gaps that are existing in the RIL may be filled with nonpublic information, and that would be something that the licensing office would have access to, once an application actually came in. I'm not saying that that exists, but just to point out that the RIL only refers to data that is public, and a large amount of it, we actually requested to be made public for the publication.

MEMBER BLEY: Okay. Thanks. That helps me.

VICE CHAIRMAN REMPE: So, just for

information purposes, on the user need, could you elaborate what they said they would do with the RIL? What would be the next step? Because I would like to better understand what this would lead to, what their intent is.

MS. BALES: So, that is, unfortunately, not identified in the user need. The user need just says what products the Office of Research will produce. It doesn't define the next steps.

VICE CHAIRMAN REMPE: What's typically then?

MS. BALES: It varies. It sometimes can be a Regulatory Guide. So, I'll say in the case of 04-01, regulatory guidance was updated, because the limits for RAA are located in regulatory guidance. In the case of 08-01, a proposed rulemaking was initiated because the findings in 08-01 called into question 50.46 criteria. So, it really depends on what the conclusions of the research are.

FFRD is currently not addressed in guidance, and it's currently not explicitly identified in regulations. And so, it's not obvious that either of those actions would be required as a prompt from this.

MEMBER BALLINGER: Did 08-01 result in

NUREG-2240, whatever the number is? The last version of fuel, that described fuel dispersal and fragmentation?

MS. BALES: So, let me go to the next slide because the last point on here is just to say that Research Information Letters do not provide guidance, and I think we've kind of covered that. I don't want to forget to mention it, though.

As we go to the next slide, NUREG-2121 is a literature review that the staff produced. Okay. So, I start with 08-01. I mentioned that its primary purpose was to establish new embrittlement criteria relative to 50.46 rulemaking. At that time, we already had seen the first example of fuel dispersal in a test that had taken place at Halden on a rod that was 92 gigawatt days, far above the license burnup limits. Because we had that information in RIL 08-01, we identified dispersal as a potential issue and said that we would continue working on it. So, RIL 08-01 will mention it.

Following that RIL, there were additional tests that were run, and it really prompted the staff to go and do a literature review and see, for 90 tests in over 30 years, what have we ever observed with respect to fragmentation, relocation, and dispersal?

NUREG-2121 is, basically, a literature review, and it reviews the past information. And the conclusion drawn at the end of that review was that fragmentation, relocation, and dispersal could not be excluded, and that, at the time, the current burnup limits were likely to prevent significant dispersal, and therefore, there was no safety concern at that time.

Additional research became available, and in 2015, the staff also conducted an analysis that looked at thermohydraulic conditions typical for specific power histories and operating regimes and did an analysis to determine how much fuel dispersal might be expected in a nominal LOCA condition. And that SECY-15-0148 concluded that, again, current licensing limits were sufficient to prevent significant dispersal. But, even in that SECY, we acknowledged that that conclusion was heavily reliant on the assumptions about burnup limits and how high burnup fuel was operated; specifically, whether high burnup fuel was located in low power regimes and, basically, experienced a more benign LOCA because of its low power.

And then, finally, now -- one more click -- we have the Research Information Letter, which is

sort of a continuation of these documents and says everything that we know as of today.

MEMBER BALLINGER: Do we know what the status of 50.46(c) is?

MS. BALES: It is still up with the Commission for a decision.

Okay. So now, I want to get into the programs that are cited in the RIL and the peer review process. The main thing I want to communicate about the data sources is that we learned a lot since 2015, when the staff last wrote about FFRD. The Studsvik Cladding Integrity Program, Phase III, was conducted completely after the 2015 SECY. Oak Ridge ran a small hot cell program that added a few additional tests, and one or two Halden tests were conducted after 2015.

The size of the circles represents the number of tests, and the transparency of each circle represents whether that information was publicly available. So, prior to the RIL, the SCIP-III data was not publicly available, and this RIL represents the first time that this team disseminated. The Oak Ridge and NRC LOCA tests were documented in public journals and NUREGs.

On the next slide.

Because the data coming out of these

programs is relatively new and there is not a full mechanistic understanding of the phenomenon, we wanted to do a purity process. It's not a requirement for a Research Information Letter, but we chose to do it because we were committed to having outside opinion and ensuring that we hadn't missed research that was relevant, and that the basis for our conclusions in the RIL were well supported.

So, we identified five individuals who already had extensive familiarity with FFRD research, either because they are conducting research themselves or through their participation in programs like SCIP and Halden. So, the names are listed here and a little bit about their background.

Going on to the next slide, I want to now talk about the outcome of the RIL. And again, I'm talking about how the RIL could be used, before I talk about the specific basis for each limit.

And as I talk about that, I want to explain a little bit about the testing that forms the basis for the RIL, because understanding how the tests were conducted is going to be important for understanding some of the conclusions that we drew.

And I'm wondering if, because I have added so much animation and when I'm presenting it's

convenient to do that, I wonder if I could just -- thank you. I don't want to cause a distraction.

But the testing that was done, almost exclusively, except for Halden, all of the other three programs that we cite in the RIL were tested on prototypic irradiated fuel, irradiated in a commercial reactor, typical fuel and cladding materials, but the tests were conducted in a hot cell. The heat was provided with a clamshell furnace. So, in the image on the lower left, you see the furnace open, and the orange square is encircling the fuel rod, a single fuel rod. And there are four heating elements that surround the fuel rod when the clamshell furnace is closed.

MEMBER BALLINGER: So, I have experience with this kind of experiment, with quad-elliptic furnaces. And is this plot an average of temperatures? Is there a detailed report that shows the individual temperatures around the fuel rod during the test? Is this an average?

MS. BALES: The plot that's shown on the lower right is the thermocouple that was used to control the furnace. So, it's located just above the center. And prior to the testing, there was an extensive qualification program done by Studsvik about

the furnace. And in that report, you can find discussion of the circumferential variation, the axial variation.

MEMBER BALLINGER: So, there is a quantification of the uncertainty?

MS. BALES: Yes.

MEMBER BALLINGER: Do you know what it was?

MS. BALES: You mean the uncertainty in the temperature at that location or --

MEMBER BALLINGER: Every 15 degrees sees a factor of two. So, it doesn't take much.

MS. BALES: Yes. So, when we're looking at oxidation, it is very important; small deviations can have a huge impact on oxidation, especially as you get to high temperature.

For the phenomenon that we're looking at here, 15 degrees plus or minus, so basically, when burst occurs and what the peak temperature is, I don't think it's as significant as if you're looking at the oxidation.

MEMBER BALLINGER: These tubes have a helical texture.

MS. BALES: Uh-hum.

MEMBER BALLINGER: Which means the

strength of the creep resistance is a function of where you are on the fuel rod. And in that case, the creep rate and the interaction between the creep rate and the time of the test can make a difference as to where the burst begins. So, has anybody done a look, a careful look, at that?

MS. BALES: The microstructure is hexagonal close-packed, and they are non -- I'm forgetting the word. They have --

MEMBER BALLINGER: Plus or minus 45, 40-degree or 45-degree texture, but it rotates because of the way the tubing is rocked or fabricated.

MS. BALES: So, as far as burst behavior and the phenomena that we're looking at here, I don't see that that is going to have an impact. Like I said, the properties in each direction are different because of the texture of the cladding, but not in a way that should vary significantly over the axial length.

MEMBER BALLINGER: These bursts are notoriously difficult to interpret.

MS. BALES: So, there was a lot of discussion about this at the Subcommittee. So, I actually added a slide on this topic as well to kind of expand on the impact of experimental conditions on

the things that we are measuring. I'm going to get to that next.

I'll just finish by saying that the segments are cut from full-length rods. They're about 30 to 50 centimeters in length. And they are repressurized. There is a pressure line that is integrated into the system and can vary the pressure, and in many cases the test conditions included variability in the pressure because that was a parameter that we wanted to investigate.

MEMBER BALLINGER: Once you go above the phased transformation, all that stuff goes away.

MS. BALES: Yes.

MEMBER BALLINGER: So, you know, depending on where the burst occurs.

MS. BALES: So, as I said, I wanted to expand on the influence of the experimental methods because the tests that were done in all of the hot cell programs had -- as I said, they are prototypic materials; they're prototypic cladding and fuel, but there are non-prototypicalities.

So, for example, if we look at the axial length, the variability of heat is going to have a big influence on the strain behavior. And so, on this image, we see a very sharp increase in strain centered

in the middle of the furnace, and there is quite a large strain. This axial profile, this strain profile, is probably not prototypic of anything you would see in a reactor. You would have a much more uniform heat applied on a length of this -- of this length --

(Internet connectivity problem.)

CHAIRMAN SUNSERI: It's the internet connection.

MS. BALES: Okay. We're back.

So, the strain profile and, most likely, the max strain are not prototypic. In addition, as I mentioned, we have short segments, and it's not obvious how to scale the short portion of the fuel rod that's going through these LOCA conditions to a full-length rod.

So, on this image, I have the X-axis burn up and the Y-axis is the mass of fuel, like the actual amount of fuel that was collected. We can't multiply that mass by any ratio of the segment length to a full-length rod. That wouldn't be meaningful to do. And finally, the burst opening size varied in the test, and it's not obvious that these burst opening sizes are prototypic.

Nevertheless, as I start to describe how

the experiments were used to derive empirical limits, I want to make the case that the empirical limits are derived in such a way to be independent of any experimental non-protypicalities. We don't use the mass of fuel collected and multiply it by the full length. We don't use the length of the cladding that experienced greater than 3 percent strain in any of our empirical limits.

So, I will return to this concept as I walk through the empirical limits, but I want to argue that they are based on the physical constraints of the cladding and diverse opening and not a skilled interpretation of the quantities measured in the tests.

MEMBER PETTI: So, just a question on the burnup. That's fairly uniform over the sample because --

MS. BALES: In these short samples, it's fairly uniform. So, in a full-length rod it would vary, but the samples of 30 to 50 were relatively flat.

MEMBER PETTI: So, to extrapolate that burnup to a reactor core, it's the peak burnup on the rod most likely or the center portion of the rod?

MS. BALES: So, what we've described, the

empirical limits would be pellet averages. And then, through an analytical tool, you would determine what the local burnup would be, and then, you would define a limit.

MEMBER PETTI: So, it's burnup, but it's the local burnup?

MS. BALES: Yes.

MEMBER BALLINGER: I've got to assume that I have the wrong slides.

MS. BALES: This slide is also new. There's three new slides. We've gone through two of them. There's only one more to go.

(Laughter.)

Like I said --

CHAIRMAN SUNSERI: Your assumption is confirmed.

VICE CHAIRMAN REMPE: Tell us before --

MEMBER BALLINGER: We all have the wrong slides.

MS. BALES: I apologize. Yes. So, like I said, after the Subcommittee meeting, there was sort of three areas that I felt deserved some time, and I added slides to facilitate that discussion. And I will get the presentation that includes those slides after this, all of the slides, except for this one at

the end.

MEMBER PETTI: So, just another question before you go. The stain profile that's shown, given that it's a short segment, the gradient with respect to distance is probably steeper than is seen in a reactor.

MS. BALES: Yes. Yes.

MEMBER PETTI: Okay. From an analytical perspective, can they can calculate anything close to this?

MS. BALES: That is discussed in the limitations of this RIL at the end. We acknowledge that the limits are based on local conditions, and that the tools that we have right now are really catered to calculating the max strain. They haven't really been calibrated to calculate the length of the (audio interference) event.

So, creep models are well-informed. And so, there's not exactly a reason to believe that we have no understanding of that, but it's behind something that deserves some further validation.

MEMBER BALLINGER: Yes, I took the liberty after the Subcommittee meeting of contacting a modeler, whose name shall remain anonymous, and asked that person, what's the strain at burst in these tests

calculated? And he says, "What do you want it to be?"

(Laughter.)

So, it's very uncertain, very uncertain.

MEMBER PETTI: Well, you know, I mean, creep, especially the time --

MEMBER BALLINGER: Yes.

MEMBER PETTI: -- I mean, there's just so many variables; it's always difficult -- always.

MS. BALES: Yes, and I think as we get into the information in the RIL, you know, Kim already mentioned it and it's really important to drive home. The RIL outlines what I call the on/off switches, like when do these phenomena start and stop? It is not the full picture. In order to really use those, there's a whole lot of analysis that has to happen.

What you're both describing in terms of what are the fuel rod conditions and exactly what is the (audio interference), but prior to that, looking at the LOCA conditions and understanding what kind of hydraulic bounding conditions these rods are being subject to, whether they actually reach the temperatures that are required -- this RIL is really just a piece of a much bigger puzzle. And I think it's important to keep that in mind when looking at what it is and what it is not.

MEMBER HALNON: Well, given that, that the picture is not clear yet, why the RIL now? I mean, what's the urgency in getting this?

MS. BALES: So, in order to do any of that analysis that would follow from this, you have to know the on/off switches. That is a key part of a more complete analysis. You have to know when the phenomenon occurs in order to say what are the implications; when is it occurring? And so, the RIL --

MEMBER HALNON: It's just puts the regulatory piece in a very precarious situation, because now you have these on/off without the full picture. What do you do with it? I mean, do you start backfitting and start setting limits? Do you come back? What is NRR going to do with this, given the fact that it's just on/off?

MS. BALES: I see our colleague in NRR stepping to the microphone.

MR. DONOGHUE: Good morning.

CHAIRMAN SUNSERI: Please state your name.

MEMBER BALLINGER: By the way, before we get started, I've been informed that, in Cinderella fashion, your time is going to be up in 20 minutes.

MS. BALES: I'd better get moving.

MEMBER BALLINGER: So, we'd better get moving.

MR. DONOGHUE: And I'll be brief.

My name is Joe Donoghue. I'm the Division Director of Safety Systems in NRR, working closely with Kim and her staff.

We expect to use the RIL to guide our next steps, and we haven't decided what they are because the RIL is not quite final, but, as Michelle has mentioned, it could be the basis for guidance. In the past, that's what we've done. But, as you're all realizing here, there is a lot of uncertainty in the information, a lot of gaps.

And what prompted us to talk about actions that we could take to update our knowledge is that industry has made it clear that high burnup fuel, you know, batches of high burnup fuel, is something that they want to pursue in license. So, we felt like we needed to update the information, the understanding that we had from 2015. I think you had a slide up there, Michelle, to show that SECY paper. And then, decide what has changed, what do we know. Do we have a basis to go further than burnup? What do they want to propose? Do they want to go higher in high burnups, then, that would be licensed by a Topical

Report?

So, what we're going to do is review the RIL, work with Research, and as Michelle pointed out, usually vendors, when they submit it, they might have information that would help fill some of the gaps, would help us understand better what we can allow to be licensed.

Until we see all that laid out, it's hard for me to say that we're going to change any of the current limits that are out there, okay, one way or the other. Okay?

So, another point, and then, I'll stop, is -- and I think you're going to get to this, Michelle. In your presentation, which was very good, I thought it made clear that the concerns about FFRD, it's not just the "FF," the fragmentation; it's the relocation and dispersal, which depends on other factors. I think you all know that.

So, we have to understand all that better before we make a decision about exactly what we're going to do in a regulatory framework. Does that help?

MEMBER HALNON: Yes, it does to some extent, which basically says that the increased burnup discussions are on hold until we get the full picture.

MR. DONOGHUE: Yes.

MEMBER HALNON: That's what I heard.

MR. DONOGHUE: Well, I'll say that we felt it was premature to try to set down guidance, because without an update to the information, it could be very conservative guidance.

MEMBER HALNON: Right. That's what I'm trying to see.

MR. DONOGHUE: We'll still having presubmittal meetings with vendors on their proposals. So, that's why I didn't want to just say yes, because there are discussions that are continuing, but they're presubmittal; we're not doing extended high burnup with views over 75.

MEMBER HALNON: Okay. So, the timeline for -- and I'll let you go after this -- the timeline to get this full picture is important, because if you're having presubmittal meetings, somewhere at some point they're going to collide and you're going to say "No," until they get the full picture. So, okay.

MEMBER BALLINGER: Now I'll violate my own previous statement. We have a case here where we have actual data, but it's highly uncertain in terms of its effect and the relationship between that data and the real world, and what one member has called "Chapter 15

hell," where you end up with a very stylized analysis that must be done.

MR. DONOGHUE: Right.

MEMBER BALLINGER: And when you tack on the uncertainty here, which results in very conservative assumptions, with the Chapter 15 analysis, it can be difficult.

MR. DONOGHUE: Understood. And that's why I'm tiptoeing around so much and saying I don't want to prejudge the staff's conclusions, until we've heard from the RIL and from all these sources, to understand how to best come to reasonable assurance/conclusion based on all these uncertainties. I mean, there's other areas, you're aware, where we've dealt with uncertainties before. This is, yes, definitely difficult.

MEMBER BALLINGER: You've got to move.

CHAIRMAN SUNSERI: Yes. I'd like to ask one question, though. Joe, you can stay for this one. I just want to understand. I missed the Subcommittee, and I apologize if this is a redundant question.

But it sounds to me like, and I heard Michelle say, that this is a compilation of publicly available information compiled to present to NRR to aid your knowledge and your decisionmaking when it

comes to this topic. So, it seems to me that -- is that the way NRR is planning to use this, as information to help them understand whatever their gaps in their knowledge are, and when they review applications, what questions they should be asking, based on public information, available information, and help make sure you get the in-depth review that you need to do versus a definitive limitation on what you can approve and not approve?

MR. DONOGHUE: Yes.

CHAIRMAN SUNSERI: That's not a very well-organized question, but --

MR. DONOGHUE: It could be -- I'm sorry.

CHAIRMAN SUNSERI: Go ahead.

MR. DONOGHUE: It could be used to put down definitive guidance, but I'm not ready to say that's exactly what we're going to do, because it may just help us inform the reviews, as you said, to understand what questions to ask, and then, we may have to somehow account for these uncertainties with conservatisms.

In other areas, you may remember a couple of years ago the coated cladding ISG that went out. It was, I think, much more solid information. The staff, we felt confident being able to issue guidance

on that that applicants could use.

In this case, right now, this is what's happening. This is what's happening right now. Vendors see the challenge and they're approaching it in different ways. We're not ready to say that, because it would be prejudging this, that one approach is better or worse than another. So, at some point, though, we think we could know enough -- and I'm not saying the RIL is it by itself -- but at some point we would have enough information that we should be able to put some guidance together. I'm just not ready to say when and how we do that.

CHAIRMAN SUNSERI: Yes, and, no, I'm not asking for that. It was just how this information might be utilized. You answered my question. Thank you.

MR. DONOGHUE: Yes.

MS. BALES: Given the time constraints, I'm going to skip a couple of slides.

CHAIRMAN SUNSERI: Don't feel overly constrained. I mean, you know, don't load your time, but take whatever time you need to get your points across.

MS. BALES: Well, I think, based on the interest that I'm hearing, there's a couple of slides

that we've prepared that will address some of this topic. And how about I go through that? And then, I'm going to skip some of it. But if there's questions based on either followup from the Subcommittee or reading the RIL, I can definitely go back to it. I just want to make sure that, before I really do run out of time, that I've made a couple of key points. So, I'm going to appear to be skipping through the slides, but --

CHAIRMAN SUNSERI: But just so I make sure, since I'm moderating this, you're the last presenter or there's more?

MEMBER BALLINGER: No, NEI.

CHAIRMAN SUNSERI: Well, NEI, they have seven slides, right. Okay, I've got it.

MS. BALES: The slides that we've presented here are all that the staff has prepared.

CHAIRMAN SUNSERI: Okay.

MS. BALES: So, I'll be speaking to a couple more slides.

CHAIRMAN SUNSERI: Okay. Great. And how far along are you into that?

MS. BALES: Not very far.

(Laughter.)

CHAIRMAN SUNSERI: Okay. Go ahead.

MEMBER BALLINGER: Think about 9:40.

MS. BALES: Okay, I'm going to wrap up at 9:40.

So, I put all of these images on the slide because I wanted to kind of give you the impression that, if you just open up a bunch of these reports that have documented FFRD research, you could look at this and say, wow, there's a lot of fragmentation there. There is a lot of phenomena that we don't really understand. Why is it happening in this circle pattern in that image? How do we make sense of all of these fragments? And you can come away thinking that this is sort of an intractable problem.

And with the RIL, I really want to argue that it's not an intractable problem; that, in fact, we know quite a bit about when FFRD occurs and, most importantly, when it does not occur. And with that information, we've presented the RIL to really allow for a focus of fuel safety analysis on only the rods and portions of the rods that matter. And I think that's really the mean outcome of the RIL, is to focus safety analyses.

So, we've addressed these five elements. I won't go through them because I'll have to speak to them in the next slide. I'm going to walk through

this outcome of the RIL talking about the focused analysis using this cartoon stylized image.

What this represents is a depiction of each assembly in the core relative to its burnoff and its operating power at a single point in life. And I use this because it will help illustrate how the RIL helps to focus the analysis from all of these rods and the full length of these rods to just a handful that actually are vulnerable to FFRD.

So, the RIL lays out fine fragmentation is not occurring in fuel rods below about 55. That means that during steady-state operation there is some pellet cracking and there is some large fragments that you will observe at the end of life, but that this transient phenomena where the fragments become more fine has only really been seen when you're getting to burnoffs above 55. So, every rod below that does not need to be examined for its susceptibility to fine fragmentation.

When you look at relocation, this is where a fuel pellet falls axially into the balloon region. This also has not been seen unless you have fine fragmentation, and it requires ballooning, which is temperature-dependent. So, only rods that are operating at a high enough power during operation, and

therefore, will see high temperatures during the transient, are vulnerable to fuel relocation. So, again, a limited number of rods that are of concern.

MEMBER BALLINGER: Is there any thought that the fine fragments may come from the rim?

MS. BALES: We have examined that, and there was some work done, sponsored by NRC, and then, followed up by SCIP, to look at the origin. For rods between 50 and 60, we see that the fine fragments are almost exclusively from the rim region. But, as you go up in burnup above 70, there's evidence that those fragments come from the entire radius, even from the center.

Dispersal is also limited. Physically, you can only disperse fuel if you have burst, and you can only disperse fuel that has moved from another part of the rod into the burst region. And so, a dispersal is also limited by the boundaries of fine fragmentation and relocation.

I forgot to mention why I put the image on the lefthand side. We've seen that relocation requires local cladding strain. If the cladding is still tightly binding the fuel, you don't have axial relocation. So, even where I'm drawing this box around rods with high enough power and the right

burnup, we're still not talking about the full length of the rod. We're only talking about the region above and below the burst which has strained to around 3 percent.

So, this dispersal zone is relatively small. The area, the fuel rods that have a concern that need to be examined for their vulnerability and quantity of dispersal is probably small and it is affected by the core loading pattern. And depending on your ECCS response, your plant design, loading pattern, and even fueling cladding designs, you may have a core that has no rods operating in this dispersal box.

The RIL also addresses transient fission gas release, and the reason is that transient fission gas release -- in other words, fission gas release that occurs during the transient, not during (audio interference) elaboration -- will increase the rod internal pressure during a LOCA event. And rod internal pressure is a key determinant for whether the rod bursts. So, accurately predicting rod internal pressure is essential to accurately predicting burst, which is essential to accurately predicting dispersal. So, accounting for transient fission gas release is required in order to correctly estimate how much

dispersal a certain core might experience.

MEMBER BALLINGER: Might we be getting the cart before the horse? Excuse me. Might we be getting the cart before the horse a little bit? At high burnup, the fission gas is mostly located on grain boundaries, I think, and if it's in the rims, for sure. And if you have a very high temperature, fast temperature transient, that fission gas may form instant bubbles and blow and cause the fragmentation, the fines.

MS. BALES: So, there is a hypothesis that the fine fragmentation has something to do with trapped fission gas release and cleaving of the pellet to further fragment it. What I'm referring to here, though, has been seen experimentally, that when a modeler is trying to predict burst or non-burst, and they don't account for transient fission gas release, they have gotten the prediction wrong. When they tune their model to account for a transient fission gas release, they can better identify the moment of burst.

So, here I'm not talking about the mechanism for fine fragmentation. I'm just simply saying that accounting for transient fission gas release is important to predicting burst.

MEMBER BALLINGER: You used the word

"tuning," and I use the word "fudge factor."

(Laughter.)

MS. BALES: Yes, that is fair.

VICE CHAIRMAN REMPE: All modelers use fudge factors.

(Laughter.)

MEMBER BALLINGER: In this case, we're serious.

MS. BALES: Well, you know, no, and to take the point seriously, these are empirical limits. They are not mechanistic models. And we have to be aware of that when we're applying them, not only just in the case of uncertainty, but just in the case of we can't apply this information beyond what it was measured against. We can't apply it to new conditions. These are highly empirical.

MEMBER BALLINGER: Which means, in layman's terms, you can't extrapolate.

MS. BALES: Exactly. Exactly.

The last item that the RIL addresses is packing fraction, and I talked about axial fuel relocation before and the possibility of fuel from above the burst opening to fall into the burst area. In non-burst rods, we care about how much fuel is located in that region because it affects the

temperature. That additional fuel needs to be accounted for when you are determining the decay heat load in that region, and that's essential for identifying the cladding temperature, which is our deterministic metric for LOCA success. Heat cladding temperature is the limit, one of the key limits for loss of coolant.

MEMBER KIRCHNER: May I ask a question? Yes, I'm looking at this -- I'll take off my mask for a moment. Isn't temperature much more important than linear heat generation rate? I'm just curious why you're applying it against linear heat generation rate.

MS. BALES: So, temperature during the transient is the key determinant. And this is really depicting the power of the operating rod prior to the transient.

MEMBER KIRCHNER: Yes.

MS. BALES: And so, it's imperfect, but I use this cartoon just to kind of depict the population of rods in the core to emphasize the point that we're not talking about the entire core. But if we're actually determine whether each of these rods experiences the phenomenon, you're right, the temperature during the transient is the key

determinant. This is just the stylized illustration to kind of scoop the situation more than it is to --

MEMBER KIRCHNER: Thank you.

MS. BALES: -- kind of (audio interference) the on/off switch.

MEMBER BALLINGER: I keep coming back to the prototypicality, if that's a word. The heat generation rate that results from nuclear heating results in a temperature profile that's way different from a furnace. No matter what you do, you can't reproduce that. And the first time you heat the fuel up, it's going to crack in real life. Has anybody done any work to see if they just do one cycle of parabolic heating that cracks the fuel, and then, runs a balloon test to see if you get any dispersal from just the fact that the fuel is cracked due to the thermal gradings?

MS. BALES: So, there were tests done in the SCIP program at 40 gigawatt days per metric, for example. So, those rods would be irradiated in the reactor. They had protypical end-of-life cracking that you would expect from steady-state operation, the thermal --

MEMBER BALLINGER: Right, but they were cracked at .1 gigawatt days per metric.

MS. BALES: Right. What I'm saying is that those rods experienced a transient, and we did not observe fine fragmentation in --

MEMBER BALLINGER: I don't mean by fine fragmentation. What I'm saying is you've got cracked fuel.

MS. BALES: Yes.

MEMBER BALLINGER: And then, you have a ballooning problem and you rupture the fuel. You rupture the cladding. Do you get dispersal of those fragments, not fine, but those fragments?

MS. BALES: So, in this RIL, we're only proposing that rods with fine fragmentation are the ones that are concern for dispersal. So, the large fragments of a lower burnup would not be --

MEMBER BALLINGER: Okay. I'm just trying to center myself on where this -- what happens when and where.

MS. BALES: Right.

MEMBER BLEY: This is more of a question for Ron, but for you folks, too. We've got empirical evidence of when we've had bursts. But if you get fuel fragmentation and begin to rearrange things a bit, you're kind of packing tighter. So, even if they didn't get bursts, if you go through any thermal

cycles, you may be really stressing that clad in unexpected ways. I don't know if anybody has played with that.

MEMBER BALLINGER: If you're not careful, in the very early days, they had basically zero -- I mean, in the early days, they had --

MEMBER BLEY: I remember.

MEMBER BALLINGER: -- basically zero gap.

MEMBER BLEY: That's what got me thinking about that, yes.

MEMBER BALLINGER: Which that was not a good thing.

MEMBER BLEY: And they broke a lot, yes.

MS. BALES: In the RIL, there is a reference to some work done at the National Labs to look at the comparison of Halden's temperature profile to the hot cell tests. So, just to kind of address, I think, the underlying concern that these hot cell tests are not simulating the temperatures -- I should get closer, yes; sorry -- the initial portion of the transient will look different when you're looking at the radial temperature profile across the pellet in the two tests. But, after about 27 seconds -- I'll say after about 30 because 27 is too -- that the axial -- sorry -- the radial temperature profile in both

Halden-style tests and hot cell tests is actually the same.

And so, while the irradiated effects -- sorry -- the effects of nuclear heating are not negligible -- sorry -- they are not non-existent; they are there, especially at the beginning, as the transient continues, there's been some analysis to show that the radial temperature profile is very similar, and it's that radial temperature profile, the differences in the temperature across the pellet, that we believe have something to do with the fragmentation. So, the fact that they're similar suggests that the fragmentation might be similar as well.

So, given the amount of time and the suggestion to wrap up at 9:40, I'm going to skip the discussion of the specific basis for each of these limits. That does not mean that -- obviously, if there are questions, I am going to go through it.

So, this is not a suggestion that we skip the material. I just want to make sure to address the third new slide. Sorry, Mr. Ballinger, that there's one more slide that I think speaks to what questions have been asked today and really the questions that started to come up on the Subcommittee about where the

RIL fits into the bigger picture. So, if it's okay, I'm going to skip to that slide, and then, I'll take feedback as far as whether I should come back into these technical details. The material in here is really explaining -- there's some good videos, but, again, I can come back to this.

Okay. I want to present this slide to come back to some of the discussion that we were just having. So, when making a determination of whether fuel dispersal is a problem, I think we have to kind of go at the very highest level of what is the likelihood of a LOCA event in the first place. We understand that this is a design basis accident. So, from a regulatory perspective, it must be analyzed. LOCAs are a design basis event. We recognize that it's a low probability event, but, nevertheless, it's a required analysis.

Then, if you are predicting a loss-of-coolant accident, there are a variety of loss-of-coolant accidents of varying severities. The testing that was done predominantly is designed to simulate double-ended guillotine large break LOCA. And so, we recognize that the technical basis that we're pointing to here is a particular type of LOCA. And so, informing this section above of which LOCA

conditions will actually prompt the conditions that we've observed FFRD is an important step.

Then, once you know the conditions that you are subjecting your rod to, then you ask yourself, well, what is the fuel response to those conditions? When do the phenomenons I'm concerned about occur and when do they not occur? And really, that is what the RIL does. It's just this one piece.

After you've determined that you experience relocation and potentially dispersal, then you want to know how the system responds. Where does that fuel go? Is there a recriticality? Are there other unanalyzed conditions that arise from fuel in the coolant that wasn't expected to be there? That happens outside of the RIL; that's after the RIL.

And then, finally, there's a lot of conservatism in the licensing basis. So, even when you're predicting some fuel dispersal or other consequences of a LOCA, we may find that the licensing basis is conservative enough to account for that, and the licensing basis isn't challenged by that new information. That, again, is outside of the scope of the RIL, but is an important step to understanding the scope.

MEMBER BALLINGER: I would very much --

oh, okay, you haven't completed the slide. Okay.

MS. BALES: I love animation.

(Laughter.)

So, it keeps going.

MEMBER BALLINGER: But I'll say it anyway because it's getting to the end. I would have liked to see on this slide a line between Research and NRR and a box somewhere below the line, I assume, that says, "Consequences."

MS. BALES: Right.

MEMBER BALLINGER: In other words, we observe it --

MS. BALES: Yes.

MEMBER BALLINGER: -- undeniable. We don't know -- we have a very large amount of uncertainty in what's going on, but unless that gets translated into consequences --

MS. BALES: Yes. So, the green box should say, "Consequences." That is what I meant.

MEMBER BALLINGER: All right.

MS. BALES: The green box is like the system response. It's, can the system and the MRC core cooling system accommodate fuel dispersal? Said another way, that is the consequences.

And what I want to communicate is that, in

order to do that analysis, you must have the boundaries of the box. The RIL establishes those. And so, you cannot possibly do the consequences analysis without knowing when you get the consequences.

And so, I am very --

MEMBER BALLINGER: But, again, I'll hate to cut you off, but I would maintain that you need to estimate the consequences first, because that gives you direction on how detailed you have to go; aka how much money you have to spend, or to force the suppliers to spend --

MS. BALES: Yes.

MEMBER BALLINGER: -- to go after this problem.

MS. BALES: You know, I think that's a fair point, and I think that others have argued that you could kind of do it either way. You could either identify where the cutoffs are, and then, determine if you can accommodate that kind of response, or you're what is the amount of fuel that I can accommodate, and then, work backwards to create your design limits to prevent that.

MEMBER BALLINGER: I just wonder whether we get ourselves trapped in what I call the Rockwell

effect. Rockwell was critical of our industry because we had a habit of piling piles and piles of conservatisms on something that was unneeded. And then, when the time came to backtrack and get rid of some of that conservatism, it became a non-technical problem, aka a political problem that was very difficult to solve.

MS. BALES: You know, I'm very empathetic to that argument. I think that that is an important consideration, especially in an issue like this.

What I will say, though, it that, at this moment, we live in a deterministic world. The regulations are set up to be what they are. We have criteria that say you must show compliance with 50.46; you must show that you're below this oxidation limit; you must show that you're below this PCT limit.

So, it's a fundamental shift. It's not something that you can just wrap around at the end and say, well, yes, technically, the regulations say this, but here's how we're going to make sense of it. It has to be done with rigor. It is definitely possible to really scale out and look at the bigger picture, and the RIL is part of that also, because in order to do that, I said you still have to know when the phenomenon occurs to do all of that work. So, the RIL

does not preclude an approach that would kind of work the problem backwards, and it doesn't preclude an approach where you have sort of risk information wrapping around the phenomena.

At this moment at this day, though, the criteria that are in place for loss-of-coolant accidents are deterministic, and we have to acknowledge that.

It is 9:42. This is the point that I wanted to make.

MEMBER BALLINGER: I look to the Chairman.

CHAIRMAN SUNSERI: We're going to be writing a letter on this. So, we want to be well-informed.

MS. BALES: Okay.

CHAIRMAN SUNSERI: Get your points across.

MEMBER PETTI: Can I ask just a question? You know, you put these extra sides to help us understand the context.

MS. BALES: Yes.

MEMBER PETTI: I worry that others don't understand the context. This document will come out. It will be public.

MS. BALES: Yes.

MEMBER PETTI: It says 55 megawatt days.

People say, what does that mean for the current fleet, which is not really what your issue is.

MS. BALES: Uh-hum.

MEMBER PETTI: But it could be misinterpreted to be that.

MS. BALES: Yes.

MEMBER PETTI: I think you need like a foreword in the document --

MS. BALES: I totally agree.

(Laughter.)

MEMBER PETTI: -- that puts this context in place, so that people don't run off -- if we're going to do it, lots of people will do it is my sense.

MS. BALES: I think that's an excellent idea. And in fact, that is definitely the conclusion we came away with from the Subcommittee meeting. Sometimes, you know, I have to say, like writing this document, I've been working with this data for a year. I've been in it, and I didn't see the potential until the Subcommittee like I did during that meeting. And I came away thinking, you know, there's some context missing. And so, at Kim's suggestion, we are going to add a foreword. I've already drafted it. We've reviewed it. And I think it's incredibly important, and I think that it's possible that this RIL did not

stand on its own the way I thought it did, and we're going to address that.

MEMBER HALNON: That would satisfy me with the NRR interaction I had relative to, what do you do with this?

MS. BALES: Right.

MEMBER HALNON: So, that would be excellent.

MS. BALES: Yes.

VICE CHAIRMAN REMPE: I think this is a great idea. Again, I'm just wondering, I mean, is this still the right time for the letter? Or should we see the foreword? I mean, you're going to get comments about that, and I'm just wondering about timing. But, again, I'm just one member and I'm just listening to this going, man, it sounds like some major improvements can be made.

MS. WEBBER: This is Kim Webber.

Yes. So, that's a good question. So, we have like a working draft. We haven't completed the draft for the foreword, but I think it's a good idea because a lot of what I said in my opening remarks, and what Michelle has talked about, is in that foreword. So, actually drafting the foreword helped us put the context into words for this presentation.

So, I don't know what your timing is for writing the letter, but we can definitely work on it, you know, probably over the next week or so. We want to make sure that our partners in NRR have a chance to weigh in and take a look at it as well.

VICE CHAIRMAN REMPE: So, we don't have January full Committee meeting. We have February and it's very packed, and things like that. But I'm listening to this going, man. I mean, we're here to help the agency in writing a letter with a lot of concerns versus a letter that says, hey, we've assessed this --

CHAIRMAN SUNSERI: We write letters all the time on things that aren't final. We say I think it would be a good idea to have a foreword. That could be a recommendation coming from us, and you do it. So, it sounds like we're in agreement on that topic already.

MS. BALES: Yes. Okay.

MEMBER BALLINGER: You know, I hate to what is going to be amounting to beating a dead horse, but -- sorry about the dead horse part. But the fact that you get fuel fragmentation and dispersal, if you want to call it that, at 55, that does not mean that it makes any difference. And that's why the

consequence thing becomes very, very important. Because we've been doing -- we've got a lot of fuel out there that's above 55, without having a LOCA, by the way.

And so, I think the foreword that you're talking about would be very informative, but something else might be also informative. And that is, there's been very little -- you know, I understand the difference or the distinction between NRR and Research. But this is one case where Research produces a document that has the data analysis in it, but the immediate use is for NRR.

And so, I wonder -- and I don't know how the RILs actually work -- whether or not there should be some NRR input, a little feedback, with respect to the foreword that you do. Maybe I'm using the wrong words --

MS. BALES: No.

MEMBER BALLINGER: -- but there's a very immediate interaction here.

MS. BALES: Absolutely. So, the RIL itself was reviewed by NRR staff and we had extensive involvement with ensuring that the language in the RIL made sense and was in the right context for NRR. The foreword would be the same. We've drafted it and we

would show it --

MEMBER BALLINGER: My guess is that NEI could have written the foreword. Their concerns are with the use.

MS. WEBBER: Well, no. This is Kim Webber. No, NEI cannot write the foreword.

MEMBER BALLINGER: I didn't --

MS. WEBBER: It's an NRC document.

(Laughter.)

It's a Research document.

MEMBER BALLINGER: No, no. It's the wrong PhD thesis supervisor. Okay.

But my point is, the industry's concerns would be addressed in a foreword, would likely be addressed in a foreword.

MS. BALES: It could be. I mean, really the foreword in my mind was really coming out of the concerns that the ACRS members asked and the kind of questions that we got in this forum.

But it's not even just that. I think the more eyes that got onto the RIL, the more that we became aware of the things that weren't said and that needed to be said. So, it's really just a fact of dissemination. The more people that see it, the more views that we can collect, and to the extent that we

are aware of potential concerns, we hope that the foreword addresses it.

It may not address all concerns. It's not designed to address all concerns. It's designed to put the RIL in context, because we started to see, as we presented it, that some of that context was missing and it was critical and it led to misunderstandings.

VICE CHAIRMAN REMPE: Can a foreword suggest this might be a great place to use a risk-informed approach, or something like that? I mean, are you allowed to do something like that, like they did with GSP-191?

MS. BALES: I think that is something we should talk more about.

VICE CHAIRMAN REMPE: I'm just curious. Yes, I'm not sure how far you can go with a foreword.

MS. WEBBER: Yes, I mean, quite honestly, you're talking about a whole different set of analysis.

VICE CHAIRMAN REMPE: Yes.

MS. WEBBER: You know, that's much broader than just the RIL.

VICE CHAIRMAN REMPE: It is, but knowing that this is a design basis type of thing, and there have been other examples in the agency where,

suddenly, people wills start thinking about the low likelihood, and things like that. This issue, it's a way for Research -- and again, it's your perspective, and whatever comes out of the letter that other members are going to be writing -- but it just seems like this would be a good forwarding-thinking suggestion for Research, that even though it's a design basis event -- and it was just a thought.

MEMBER BALLINGER: Yes, one last thing, I guess. When I read through the RIL, I was looking at all the data and everything, and then, I got to the appendix.

MS. BALES: Uh-hum.

MEMBER BALLINGER: And that struck me as ordering on guidance. Well, it is guidance, actually. There's a suggestion of the model to use. And so, that's what got me a little bit worried that it's not information; it's guidance.

MS. BALES: So, I think we had to be really careful with the language that we chose, and I think we made an effort to scrub things that smelled like guidance. I think the disclaimer at the beginning of the RIL has to stand in for any interpretation. It clearly says this is not guidance. And if the language is received that way, then, you

know, we can look at it again, but I think that the disclaimer at the beginning of the document should supersede it.

MEMBER BALLINGER: Yes, I'm not a lawyer. So, I don't know what magic words get interpreted. I looked at it as guidance.

MS. BALES: So --

CHAIRMAN SUNSERI: I'm kind of thinking of this as the Committee has delved into deliberation at the same time we're getting your presentation.

MS. BALES: Yes, I was just going to say, I'm kind of locked up --

CHAIRMAN SUNSERI: I'll be lenient with the time because we have a whole hour for deliberation. We have some other things that we need to do during that time, but, please, just go ahead with your presentation. Get the points you want. We'll have time for NEI. Even if it's after 10:00, we'll accommodate them. But more than accommodate them, we want to hear from them. But go ahead with your presentation and give your key points.

MEMBER PETTI: I suspect, Matt, at this point, I think we can still write a letter.

CHAIRMAN SUNSERI: So, can you talk more into the mic?

MEMBER PETTI: I still think we can write a letter in this meeting. We're delaying, you know, we know what February and March is.

CHAIRMAN SUNSERI: Yes, yes.

MEMBER PETTI: It's just we're making our own -- I trust them to write a credible foreword to put this in context.

CHAIRMAN SUNSERI: Yes, yes, yes.

VICE CHAIRMAN REMPE: And we can offer suggestions on what's in it.

MEMBER PETTI: Right. We can put some in the letter, but I don't --

CHAIRMAN SUNSERI: Yes, I think they're getting what they want out of this, a lot of feedback from this Committee --

MS. BALES: Uh-hum.

CHAIRMAN SUNSERI: -- and we'll formalize it in our letter, but there's other informal stuff that you're already probably going around as well. So, please continue, Michelle.

MEMBER BALLINGER: So, that's new slide No. 4.

MS. BALES: No, no, no, this was in there before.

MEMBER BALLINGER: Oh.

MS. BALES: I promise you there's only three new slides, and we've now covered them all.

This was very briefly discussed at the Subcommittee meeting, and I'm only briefing going to acknowledge it here. The RIL doesn't discuss consequences. It simply acknowledges the technical disciplines that could need to be analyzed for consequences and points to the mention of those same topics that have been in our documents since NUREG-2121 and 2015. There's nothing new there.

I mentioned before --

MEMBER BLEY: I'm sorry.

MS. BALES: Yes?

MEMBER BLEY: Is somebody actively at work on considering those issues, and are we going to hear about that at some point?

MS. BALES: So, I think coming to the concept of working the problem backwards, and understanding where does the investment need to be made --

MEMBER BLEY: Uh-hum.

MS. BALES: -- there was a point where I think we believed that many of the licensing approaches would use a demonstration of no burst --

MEMBER BLEY: Okay.

MS. BALES: -- as a path forward to disposition fuel dispersal. So, basically, they, you know, the vendors, could introduce sort of operating limits for high burnup fuel that ensured that they were not operated in a manner that would eventually burst.

If that is a licensing approach taken, there's no need to look at consequences because those consequences only arise in the event of dispersal. The research that would be needed --

MEMBER BLEY: Well, I guess I hang on that one a little bit from what we talked about a little while ago, which is if we do get internally, because of all this cracking, you'll actually get some reconfiguration so we're highly packed, it might not be the burst phenomena we've seen so far; it might be something more akin to what we saw 50 years ago. Yes.

MS. BALES: So, when I talk about the consequences on that slide, I'm talking about, specifically, the consequences of dispersal, but you're right that relocation and packing fraction are also addressed are also addressed in the RIL.

There are models already in some fuel performance codes that predict fuel relocation and actually have packing fractions, and those could be

further validated with existing data or new tests.

MEMBER BLEY: Okay.

MS. BALES: So, I don't think of the hill as as high to climb in that area. The assessment of consequence analysis I think is going to be really challenging because a lot of analytical tools that could be brought to bear are not based on the exact conditions that are occurring here.

MEMBER BLEY: Right.

MS. BALES: Whether they're actually valid for this type of analysis is not obvious to me. So, that seems like an analytical exercise that warrants a lot of scrutiny.

MEMBER BLEY: Yes, I agree, and back to my question, is anybody at Research working on that already and under some support?

MS. WEBBER: So, this is Kim Webber.

MEMBER BLEY: And if they see something happening, we'll hear from them?

MS. WEBBER: You know, we've talked a lot about that, quite honestly, about using some of our thermohydraulic codes to assess that, but the challenge, as Michelle said, is there's no way to validate what goes on in the code. So, it's not like we haven't -- so, we've talked about it. I'm not sure

we have talked with our partner office about the extent of doing that kind of analysis or calculation. So, it's something that we have discussed, but we haven't moved forward on it.

MEMBER BLEY: It's good you're thinking about it.

MS. WEBBER: Yes.

MEMBER BLEY: So, that part is good. And I suspect if you do modeling and you see something that's interesting, that would suggest how we might get experiments to help out.

MS. WEBBER: Correct.

MEMBER BLEY: Okay.

MS. WEBBER: Yes, thanks, Dennis.

MS. BALES: So, I'll spend a couple of minutes talking about limitations, because this has also already come up. In a highly empirical document like the RIL, we already talked about it's not possible to extrapolate beyond where the experiments have gone.

Two that come to mind particularly are doped fuel and coated claddings. It's physically possible that doped fuel, which has advertised as different transient fission gas retention behavior, could have an impact on FFRD, and coated claddings

have been shown in some cases to have different ballooning and burst behavior. And we've seen that ballooning and burst behavior as key to the phenomena that we're concerned about here.

Today, the RIL would not cover doped fuel or coated cladding, and the RIL states that. But we imagine that this would be an area that, with some additional information, could be addressed in perhaps a revision to the RIL.

We already talked about the second one a little bit here. The prediction of cladding strain is a key factor in using the limits presented in the RIL, and I think more work should be done to validate models for balloon length, for example.

Burst opening size. We didn't get into this. It's in the slides and we covered it in the Subcommittee. But burst opening size is a key determinant for how much fuel dispersal that you would expect, and models today are not calibrated to burst opening size. Work that could develop such a model would be incredibly valuable to reduce the conservatism on dispersal quantities. That's for them in the RIL.

The first point on this slide about burnup, I didn't talk about it too much here, but I

think we talked about it in the Subcommittee, that all of the empirical limits are presented as a function of burnup, but even though we don't have a fully mechanistic understanding, it's very reasonable to expect that burnup is not the primary determinant for these phenomena. It's probably something like porosity or other sort of local, microscopic fuel pellet features.

And if further research really delved into some of those parameters, we may be able to derive a function, some of these limits as a function parameter other than burnup that reduces the scatter that we've seen in the burnup plots.

So, SCIP-IV is a continuation of the SCIP-III program. We expect that that program may address some of these limitations that we've already identified.

And we talked a little bit about analysis. We pointed to the work that was done in 2015. There is work to revisit the approach that was used in 2015 to draw the conclusion that this wasn't an immediate safety issue. We want to be able to replicate that kind of calculation easily and perhaps for NRR on a confirmatory basis as applications come in. So, we're building our tools to allow for that. And those are

the two main things that we're going to be active on in the next year or so.

But I think to pull back when I think about the RIL as a foundation for the next step, I see it as this is what we know today. It identifies some of the gaps. It explains what we know, but also a little bit about what we don't know. And I fully expect that some of those gaps will be filled in.

And if there's a more mechanistic understanding, there could be a point in the future where the RIL is completely superseded by a better understanding. That would be completely acceptable. That does not negate the value of the RIL today. What it does is prompt a conversation that's meaningful, that's looking at what really matters.

And so, when I think about the RIL as a foundation for the next steps and a potential for the building that grows on top of it to be really more relevant than the foundation itself, I think that helps to put the RIL in context. It's what we know today, and it should form the basis for ongoing discussion about where there is value.

And as I mentioned also, licensing approaches have a huge role to play. What licensing approaches require will vary, and where the investment

needs to be made in order to do additional research, additional analysis, kind of all comes from how far the RIL, how close the RIL gets to serving the licensee needs. And to the extent that it doesn't get all the way there to a licensing approach, it defines the work that needs to be done in a way that I don't think is being done right now.

MS. WEBBER: Can I also add, so in terms of what's next also, you know, because we did hear the comments that NEI made at the Steering Committee meeting, you know, we're also aware that there is interest in providing feedback on the RIL. And, yes, so we've talked internally about, when there is new research that is available that will help understand or expand the understanding of this phenomenon, we can always revise the RIL to include whatever research is going to be made available over the next several years, especially with SCIP-IV.

The other thing that we did talk about is that, beyond the RIL with the development of any kind of regulatory guidance, there's always opportunities for stakeholders to express their views and opinions on whatever regulatory guidance may be developed as a result of that.

Additionally, because this is such a high

visibility topic with industry, we have frequent engagements with industry on topics such as this. And I know that Joe Donoghue is leading the charge to plan a high burnup workshop. So, that will be a public engagement where NRC and the industry will make presentations on various topics associated with high burnup.

Additionally, there are technical meetings between the staff and international counterparts, including EPRI, where this topic will be discussed in further detail.

So, I just wanted to put that kind of wrapper around some additional notions of what's next.

CHAIRMAN SUNSERI: All right. Is that concluding your remarks?

MS. BALES: Yes, at this point, the only material that would kind of go into the technical basis is if there are specific questions. But I think all of the key points have been made in --

CHAIRMAN SUNSERI: I think you all thoroughly did that during the Subcommittee remarks.

Okay. Good. Well, thank you. That was very, very informative.

Ron, do you have other --

MEMBER BALLINGER: Yes, now we have NEI.

I think they're still on standby.

DR. CSONTOS: Yes, all set.

MEMBER BALLINGER: And Al is in.

Since we've gone a ways over, should we take a five-minute break?

CHAIRMAN SUNSERI: We can take a five-minute transition.

MEMBER BALLINGER: So, then, NEI get their slides and --

CHAIRMAN SUNSERI: Yes, get their slides up.

MEMBER BALLINGER: -- make sure everything works?

CHAIRMAN SUNSERI: Yes, that would be fine.

MEMBER BALLINGER: So, we'll take a five-minute break.

CHAIRMAN SUNSERI: We'll resume at 10 after.

MEMBER BALLINGER: Yes, 10 after, five more minutes, 4 minutes and 49 seconds.

(Laughter.)

CHAIRMAN SUNSERI: Did I read that wrong? Okay, we'll make it 15 after then.

MEMBER BALLINGER: Make it 15.

CHAIRMAN SUNSERI: You know, there's three clocks in here. Sorry.

Fifteen after.

MEMBER BALLINGER: Fifteen after.

(Whereupon, at 10:05 a.m., the foregoing matter went off the record and went back on the record at 10:15 a.m.)

CHAIRMAN SUNSERI: Hey, welcome back. I will reconvene the ACRS meeting at this point and I'll transfer it back to Member Ballinger, who will go to the NEI presentation.

MEMBER BALLINGER: Thank you, Mr. Chairman. Thank you, Mr. Chairman.

I guess we just turn it over to Al Csontos and go with the presentation.

DR. CSONTOS: Okay. Can you hear me okay?

MEMBER BALLINGER: We can. I can.

DR. CSONTOS: Okay. Thank you.

Yes, I wanted to say thank you to the Committee for providing us this opportunity to present our industry comments and perspectives on the RIL.

CHAIRMAN SUNSERI: Keep going.

DR. CSONTOS: We're good?

CHAIRMAN SUNSERI: I'll silence. Please hold on for me.

DR. CSONTOS: Good to go?

CHAIRMAN SUNSERI: Okay. All right. Go ahead.

DR. CSONTOS: Okay. Thanks.

So, I just want to say thanks again for providing the opportunity to provide our comments and our perspectives on the RIL.

Really, the comments that we're going to have here and the concern really is an echo of both the Subcommittee and the full Committee (audio interference) with the staff. Really, it's we're rehashing much of the same questions and comments that you have provided.

We will start with two slides on general overarching comments, two slides or three slides on specific technical comments. And these are just three that we picked. We have numerous more comments that we could provide, but in the time allotted, we thought providing you these three specific comments would suffice. Okay?

So, yes, we just heard the concerns of the extension of the RIL to regulatory application. And the industry agrees with that question. And we also

agree with the staff position in the SECY letter in 2015, 0148, with respect to the FFRD research not indicating a need to require additional new requirements in the 50.46 rulemaking.

And I just want to say that we heard the concept of the foreword. That's a great -- you know, I fully support the concept of the foreword. I do not support the notion that we're going to write the foreword, but folks are on to say no. We do not anticipate -- we're hoping to see that ahead of time as well, so we can comment on that.

But, really, ultimately, the bottom line is that we believe there are significant benefits for taking the time to consider and incorporate a broader technical review and comment period, like other NRC documents, NUREGs or similar to RIL-1101, which provided multiple rounds of review and comment periods from the broader technical community, including industry technical experts.

In fact, yesterday, we got an email from an international technical fuel expert asking how they can provide comments to the RIL because of the concern that we're going to highlight in the next slide, which is the significant amount of conservatisms that they see in the RIL. And so, we asked them to participate

or to call into the meeting, but we're not sure if they are, if they made it and will provide comments here.

But, anyway, this is slide 3, and a bit more general comment. As written today, the draft RIL is a conservative application to certain thresholds and models from specific datasets. And this draft RIL may be incomplete, in the absence of appropriate assessments of certainly the levels of conservatisms and, also, to assess the complexity of the technical topic. There just seems to be that there's an excessive conservatism in the RIL.

Secondly, the RIL does not offer an interpretation of the uncertainties or conservatisms within the experimental database -- experiments using nuclear heating versus experimental electrical (audio interference) heating, for example.

And again, we just want to reiterate that, per the past person I talked about, the RIL-1101, we'd like to have an opportunity to provide our technical comments prior to the publication, just the broader technical consensus.

Next slide.

So, the specific examples now. We've identified a couple of inconsistencies in the report,

and we thought we'd just highlight them here, and maybe the staff can take a look at them and maybe revise or do what they will with it.

But the RIL references Argonne National Lab Test ICL No. 2 as a primary basis for establishing the fragmentation critical pellet average burnup of 55 gigawatt days per MTU. And those tests, though, used BWR, so the rod average burnup between 55 to 57, which would imply higher local burnup throughout the middle section of the rod. And we confirmed this through email correspondence with Mike Malone, that that's probably around 64, approximately 64. Okay?

So, figure 3 in the report shows two data points near 60 gigawatt days per MTU with fine fragmentation near zero. And those PWR rods were tested within the FISA program, with a rod average of 55.2 gigawatt days per MTU, and showed no fuel loss during the LOCA test.

The SCIP-III results at the segment formed of 50 gigawatt days per MTU in figure 3 indicates a relatively small degree of fine fragmentation compared with the test with second burnup exceeding 65. The specific test was a BWR rod. And while some smaller fine fragments were observed, the majority of the fragments were greater than 2 millimeters, contrary to

figure 3 in the draft RIL. And in the SCIP-III program, it states that 90 percent of the fragments were larger than 1 millimeter.

So, based on the test data, the onset of the measurable fine fragmentation -- so, the conclusion could be altered based upon some of these discussions of the dataset. And based on that test dataset, the onset of measurable fine fragmentation appears to be near 50, not 55. So, I just want to bring that out to you.

Next slide.

So, the RIL states that the staff recommends a model that will predict the mass of the fuel dispersal to be -- you know, I don't want to read it to you, but this approach right here we see as having several unnecessary conservatisms. It ignores the effect of the burst opening area. These are comments, you know, in a lot of ways they're very similar to the comments that were made by the ACRS Subcommittee and full Committee, but we're going to go into specifics there.

The burst area, you know, that's demonstrated in SCIP-III shows a strong influence of the amount of dispersed, but that goes to some of the comments about the consequences. It ignores the

effect of fragment size distribution, which has also been demonstrated in SCIP-III to be important. And it ignores the core-wide average in effect of individual rod uncertainties in terms of the conduct of the fuel dispersal analysis with respect to large, you know, over 100 number of rods. And in this case, we're just saying that these are more accurate ways to possibly look into some of these areas.

Next slide.

And we wanted to highlight that there are other interpretations of FFRD-related phenomena with the same datasets. And so, here are three examples. I remember in the Subcommittee there was a lot of discussion about the Capps paper. We threw in two more. Now these reports and these papers were cited in the RIL, and they acknowledge the complexity of the phenomena. Michelle just talked about the complexity of the phenomena and the different database.

But the question here about going to conservative interpretations with the draft RIL is really, you know, it's limiting, we think, the benefit and the value of the RIL.

So, last slide. You know, in summary, three major points that we just want to make.

We believe this is a conservative

treatment of a highly complex technical topic. We talked about this or the ACRS talked about this just before me with Michelle's presentation. A lot of dependencies.

We are concerned with the extension of this draft RIL to regulatory application. The foreword does help, but having a broader technical consensus or a broader technical community review and comment on the draft RIL, like the NRC did with the RIL-1101, we think will provide benefits to NRC and subsequent application to the regulatory domain by providing a broader technical consensus and more technical, I guess you could say robustness in terms of getting the broader community to speak to it.

But, you know, I think I'll end up with I think one of the ACRS members mentioned, asked the question of why the rush. And I think that's what we're wondering, too. And we would really like to see about getting a broader consensus here by going through at least a round of review of our comments to be updated or to be revised in the current draft RIL, because the RIL is still draft.

And that's our concluding remarks.

MEMBER BALLINGER: Thank you.

Let's see, how should we proceed? Should

we have a little period of Q&A from the Committee?

CHAIRMAN SUNSERI: We do, but I don't want to overlook the public comments.

MEMBER BALLINGER: Yes, I'm just trying to -- which comes first? Maybe we should have public comments first?

CHAIRMAN SUNSERI: I think we should call for public comments now.

MEMBER BALLINGER: Okay. I'm assuming that there are people listening, and that if they would like, if the members of the public would like to make a comment, is it still *6?

CHAIRMAN SUNSERI: *6.

MEMBER BALLINGER: *6, and make your comment, please. There's a lot of phone numbers there.

CHAIRMAN SUNSERI: So, just let me restate that clearly. Members of the public, if you wish to make a comment, you can do so at this time by unmuting your line and using *6, state your name, and provide your comment.

Additionally, if you like, you can send us written comments as well. Send them to the Designated Federal Officer, Zena Abdullahi.

(Pause.)

Any comments?

(No response.)

All right. That's the public.

I would also extend the courtesy to anybody on the Teams invite, if they want to make a comment.

(No response.)

All right. I'm not hearing any. So, Ron, I guess you can take it back and facilitate any questions from the Committee now.

MEMBER BLEY: Yes, I have a question about process, I guess. I'm definitely unfamiliar with the RIL, and we have never, as far as I can remember, had a presentation of a RIL before the Committee. I don't think so.

MEMBER BALLINGER: That's --

MEMBER BLEY: Am I wrong?

MEMBER BALLINGER: Yes.

(Laughter.)

MEMBER BLEY: Well, I'm sometimes wrong, but never in doubt.

MEMBER BALLINGER: But that's not really relevant to our discussion.

MEMBER BLEY: Okay, but another part of this might be that, were this to be used to produce a

guidance document, would the review process by the public comment process of a guidance document, would that be one way to do it? I mean, what Al is proposing is that you have, in effect, a review process of a RIL. I'm just curious.

MEMBER HALNON: One thing, I'm concerned if you get to the guidance portion, we're so far down the road that --

MEMBER BLEY: Yes.

MEMBER HALNON: -- to effect a significant change or eliminate the guidance is going to be almost difficult. There's got to be something before that.

And, Kim, you mentioned a lot of interactions, but it sounded like they were kind of anecdotal interactions as opposed to physically, I mean specifically on this RIL and the conclusions, you know, interim conclusions being made by the RIL.

MS. WEBBER: Yes. So, the interactions that I was speaking about are really to talk about the information in the RIL in a public setting. So, that's the intent of the public interactions as we envision them today.

I don't know if that clarifies your --

MEMBER HALNON: Do you see a GSI coming down the road from this? Or is it too early to tell?

MS. BALES: So, I didn't mention it in this presentation, but there was a Generic Issue Opinion for fuel dispersal sort of in parallel with the rulemaking activity. And there was --

MEMBER HALNON: That's 50.46(c)?

MS. BALES: Correct. Sorry. A 50.46(c) rulemaking. And the disposition of that was closely linked to 50.46(c). So, that's sort of a different subject, whether that conclusion would still be valid. But it was already envisioned that this could be something that needed to be addressed and --

MEMBER HALNON: So, that GS is still open then?

MS. BALES: It's been closed, based on, at the time, plans with the rulemaking.

MEMBER HALNON: So, I guess I would encourage some specific discussion, since this has got such wide-ranging impact down the road. And it sounds like the industry is coming in with kind of an opposing view, saying that we can go bigger. You're saying we can go smaller. You know, it's he says; she says at this point, but somewhere we've got to come to a meeting of the minds, so there's not a lot of resources wasted on both sides trying to get a limit that no one is going to be able to buy into because of

incomplete information.

MS. BALES: So, there's a lot of ways that we can answer the question. I think what I'd say is that the RIL is a summary of existing information. Should new information become available, especially information that contradicts or expands the limits in a different direction, we would have to review the RIL.

Without new information, if it's really just a matter of interpreting and discussing how to view the existing information, I think that that is a totally valid thing to happen within the guidance development process. The guidance development process with public meetings and public comment periods would allow for that interaction.

I don't think that the existence of the RIL and statements in the RIL would overly restrict the discussion that could come from a guidance. Because, really, in guidance, you start to examine how the information will be applied; where uncertainties would be treated.

And so, I think one of the reasons that it's convenient to use a RIL is there is some flexibility in the process. I mentioned that ACRS is not required; peer review is not required. In this

case, we elected to do both because we felt that that was something that would enhance the value of the RIL.

So, I don't want to say that, you know, it's a really rigid process, but it's something that we should understand where fits in this bigger picture, and guidance has its own process that allows for some interaction that I think is what industry is pointing to, the need to understand how it's applied.

MEMBER HALNON: Okay.

MS. BALES: I'm not sure that going into the RIL and massaging what it says is really going to get there.

MEMBER HALNON: Yes. No, I'm not suggesting changing the RIL, because you're right, it is what it is from the standpoint of the data. The foreword that you write, though, should probably recognize that whenever you put a number out there, it gets legs --

MS. BALES: Uh-hum.

MEMBER HALNON: -- and it tends to start becoming normal language to people, and it becomes now a brighter and brighter line that's impossible to cross because it's out there.

MS. BALES: Uh-hum.

MEMBER HALNON: So, I would suggest that

the foreword be very specific to that point, that this is not meant at this point to be any kind of regulatory limit or suggest a limit or, you know, be used going forward with guidance without additional information, whatever the -- your language, not mine. But I'm just concerned that, you know, having it -- we all love a number.

MS. BALES: Yes.

MEMBER HALNON: We all love bright lines, and we tend to equate those two together when we see it.

MS. BALES: Yes.

CHAIRMAN SUNSERI: Any other member comments, questions?

MEMBER BALLINGER: Other comments?

MEMBER PETTI: Yes, just one. I was a little concerned on the NEI's technical comment about the burnup. I think we should run that through Al.

When I first saw the 55, what struck me in Subcommittee was it's based on a photomicrograph. That's all we have. But it sounds like there's more than that. There's no quantitative, because it was done, I guess, a while ago, before, let's say, we had the protocols in place that they have now for SCIP and --

MS. BALES: Right. So, I agree with you that -- you know, I saw that comment this morning and looked up in the NUREG, and we need to clarify that in the RIL because it is accurate to say that the value for that was the right average, where the rest of the reported results are segment averages.

What I'll say, though, is a few points. One, SCIP-IV is looking at the range between 40 and 60 because there's so little data --

MEMBER PETTI: That was my other question. So, great.

MS. BALES: Yes. No, it's something that, I mean, the whole SCIP community has been scrutinizing these results, too, and recognizes that we really don't have a good picture of the transition because our last known fine fragmentation is at 45, and then, we don't get anything until 60 in some cases that there has been fragmentation observed.

And you're right that the SCIP protocol quantifies the fragment size and micrograph does not. And that makes it a mismatch in the robustness of that, to anchor the point. But I expect that, with SCIP-IV data, we'll learn more.

But, also, the trendline that we would have drawn, if we only had the SCIP data, would have

intersected at 55 anyway. Because, as I said, where we know that there was no fine fragmentation was at 45, and then, at 60, there was already some. It was small, but there was some. And so, it's somewhere below 60.

MEMBER PETTI: That's probably worth a footnote in the document, I think. You know, that, hey, if you take that out, you're --

MS. BALES: No, I think that that's -- yes.

MEMBER PETTI: That's all.

MS. BALES: Yes.

CHAIRMAN SUNSERI: Anybody else?

(No response.)

All right.

MEMBER BALLINGER: No others? Okay, I'll turn it back to you.

CHAIRMAN SUNSERI: Well, okay. Thank you, Ron. Thank you, Staff. Thank you, NEI, for the presentations. I found them to be all informative. I think the Committee did as well, based on the questions I heard asked here. So, thank you for taking the time to put that together.

So, at this point, we do have a draft report letter, a letter report, that we are preparing.

And I'd ask Ron, if you want to pull that up, we'll do an initial read-through and see if we can get Committee major comments on that. We can go to 11:00, maybe a little after, but not much more.

MEMBER BALLINGER: That's fine.

(Whereupon, at 10:37 a.m., the Advisory Committee went into closed session.)

Research Information Letter 2021-13: Interpretation of Research on Fuel Fragmentation, Relocation, and Dispersal at High Burnup

Briefing of the Advisory Committee for Reactor Safeguards

December 1, 2021

This presentation will address…

FFRD history at NRC

The programs cited in the RIL and the peer reviewers used

The outcome of the RIL

The basis for empirical thresholds included in the RIL

Other Matters

This presentation will address…

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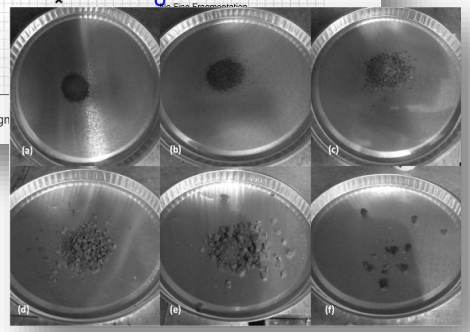
Why a RIL?

Research Information Letters

Research Information Letters (RILs) are documents issued by the NRC's Office of Nuclear Regulatory Research to the NRC regulatory and regional offices that summarize, synthesize, and/or interpret significant research information relevant to a given technical area, provide new or revised information, and discuss how that information may be used in regulatory activities. RILs can improve regulatory efficiency and effectiveness by providing important, pertinent information in a timely, concise, and comprehensive summary.

If you have questions about a RIL, please contact us for assistance.

	2021							
2000s:	2020	2019	2015	2014	2013	2012	2011	2009
	2008	2007	2006	2004	2003	2002	2001	



RILs have been used in the fuel's area:

- RIL-0401, "An Assessment of Postulated Reactivity-Initiated Accidents (RIAs) for Operating Reactors in the U.S."
- RIL-0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46"

A Research Information Letter does not provide guidance.

FFRD history at NRC

- RIL 2008-01, “Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46”
- NUREG-2121, “Fuel Fragmentation, Relocation, and Dispersal During the Loss-of-Coolant Accident”
- SECY-15-0148, “Evaluation of Fuel Fragmentation, Relocation and Dispersal under Loss-of-Coolant Accident (LOCA) Conditions Relative to the Draft Final Rule on Emergency Core Cooling System Performance during a LOCA (50.46c)”
- RIL 2021-13, “Interpretation of Research on Fuel Fragmentation, Relocation, and Dispersal at High Burnup”

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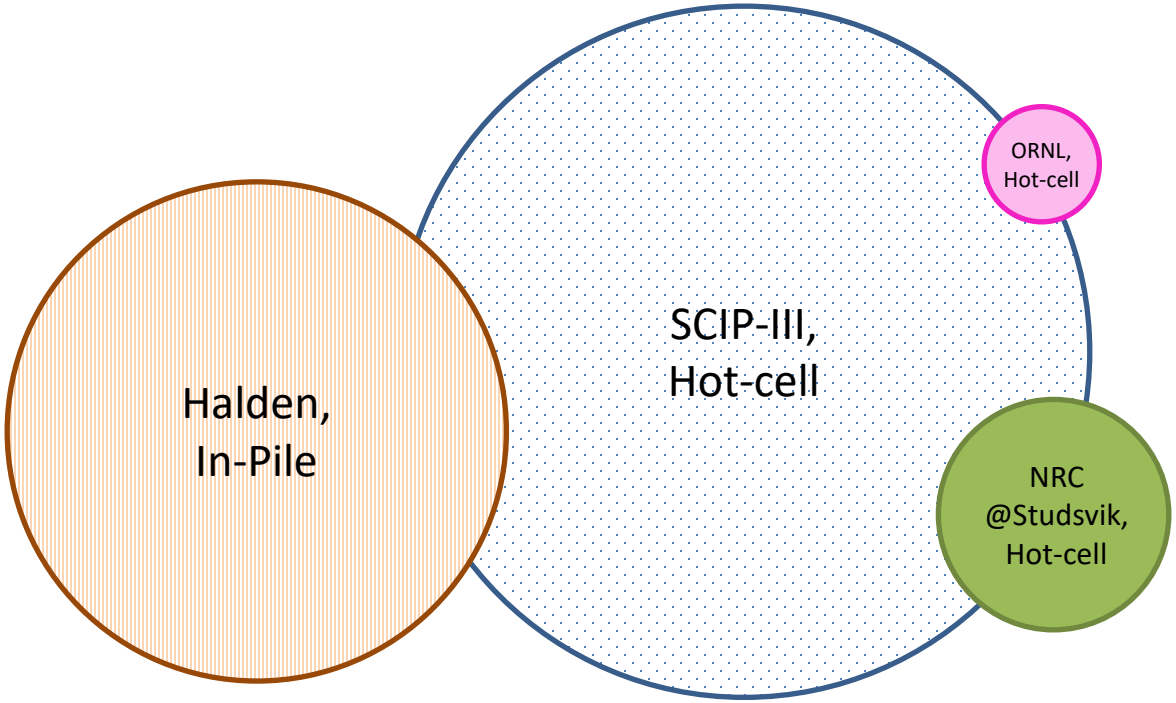
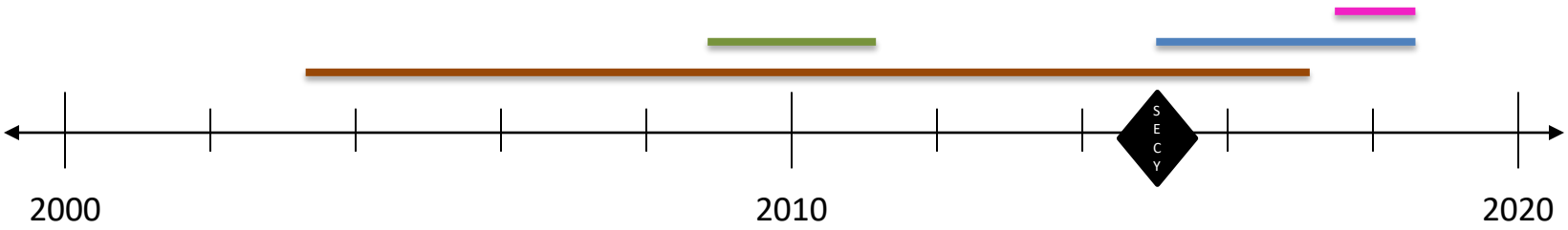
Data Sources for RIL





Peer Review Group

- Ad hoc, issue-focused group. Reviewers selected with extensive familiarity of FFRD research
  - *Nathan Capps, ORNL* – Author of two significant publications on FFRD, extensive experience modeling aspects of FFRD and collaborator in ORNL FFRD experimental program
  - *Tatiana Taurines, IRSN* – Extensive experience modeling aspects of FFRD and leader in SCIP program review group discussions
  - *Fabiola Cappia, INL* – Collaborator in FFRD publications, lead for INL PIE campaigns of HBU fuel, extensive work examining evolution of fuel microstructure with burnup
  - *Ken Yueh, EPRI* – Designed and led FFRD research campaigns at Studsvik for EPRI and NSUF at ORNL/INL, leader in SCIP program review group discussions
  - *Daniel Jädernäs, Studsvik* – Collaborator in SCIP experimental design and expert in SCIP results

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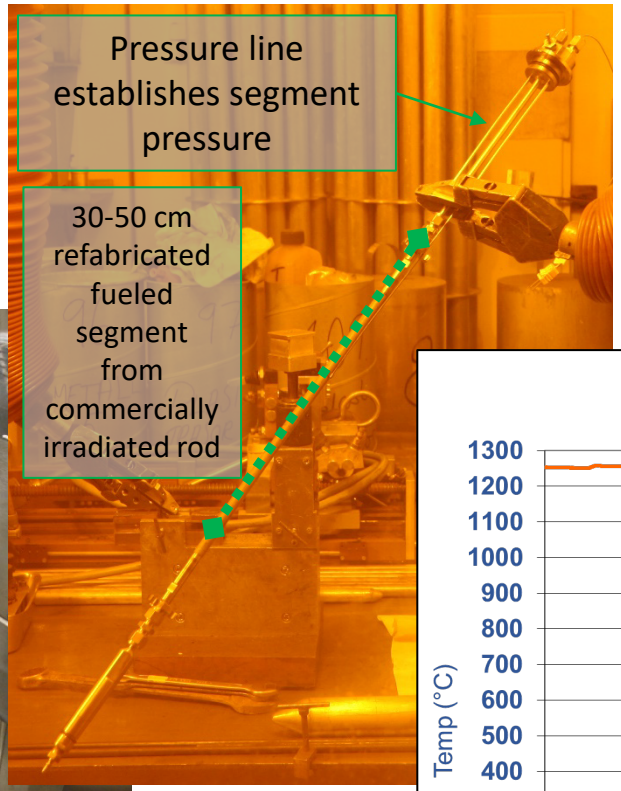
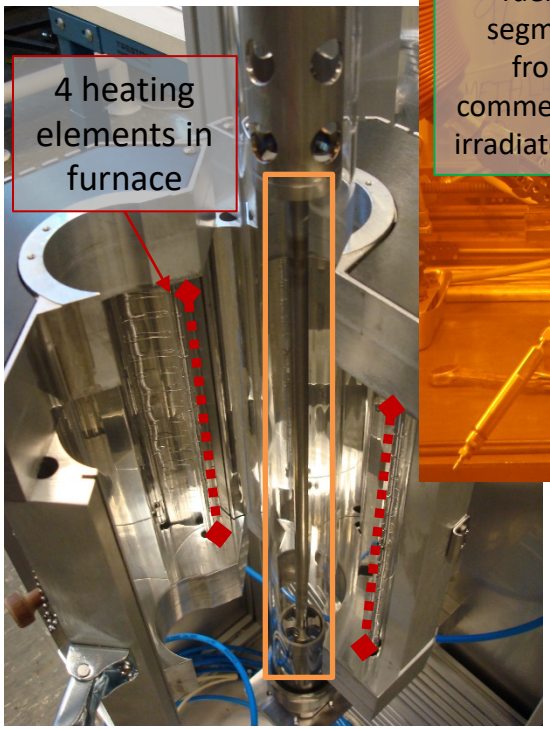
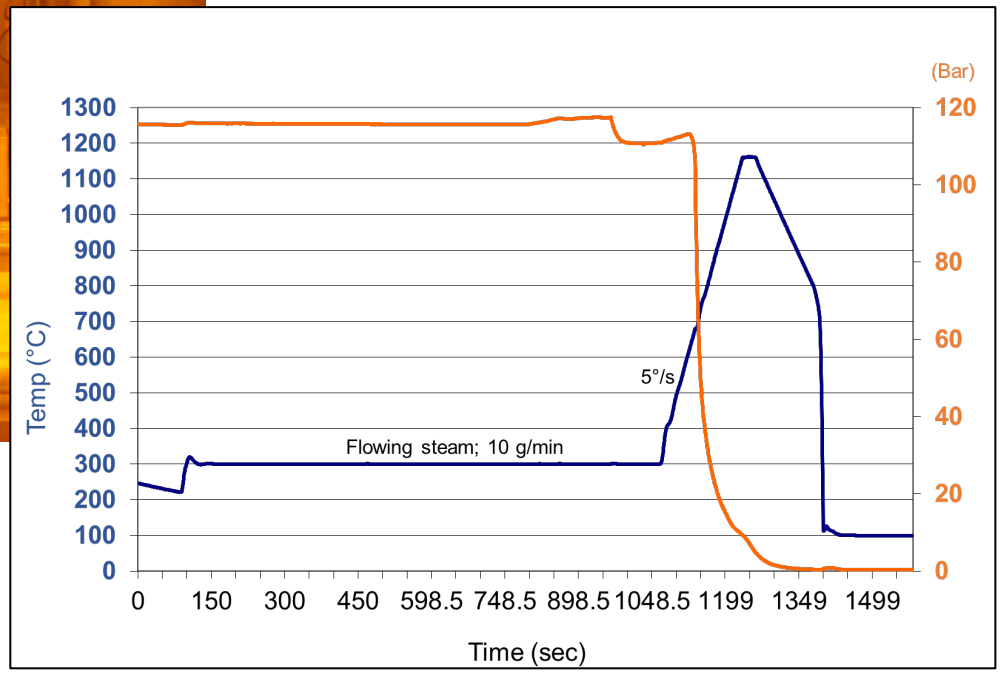
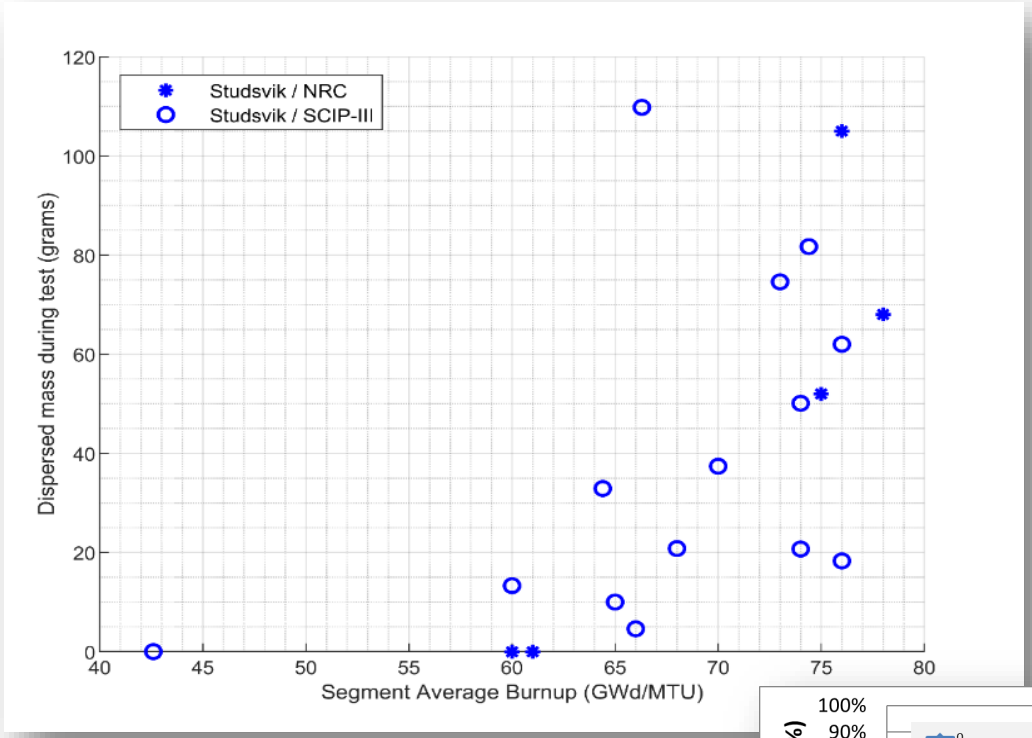
Hot-cell testing to simulate Loss-of Coolant Accident condition

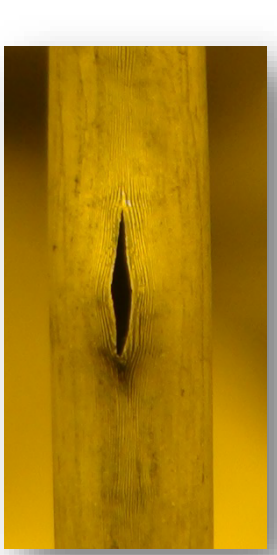


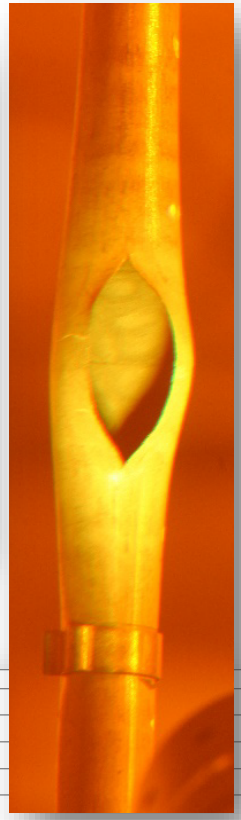


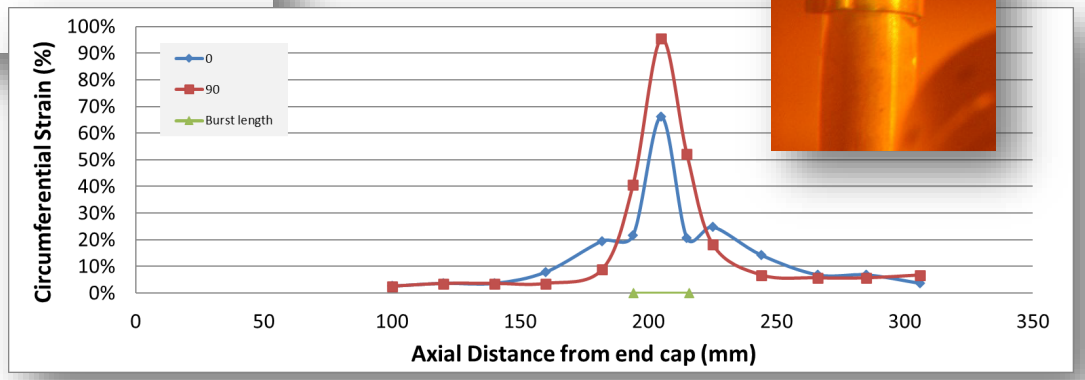


Influence of experimental methods



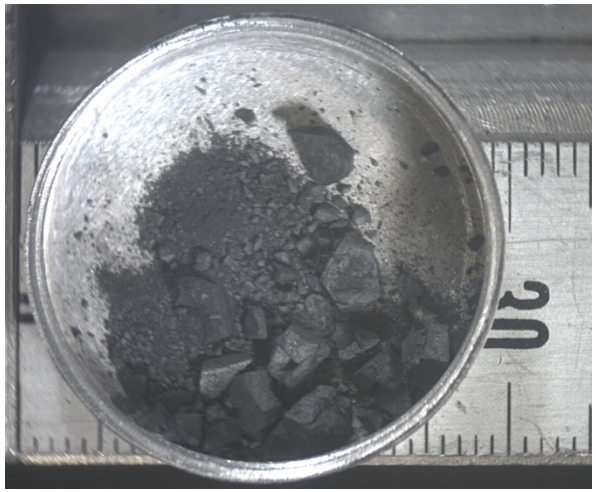


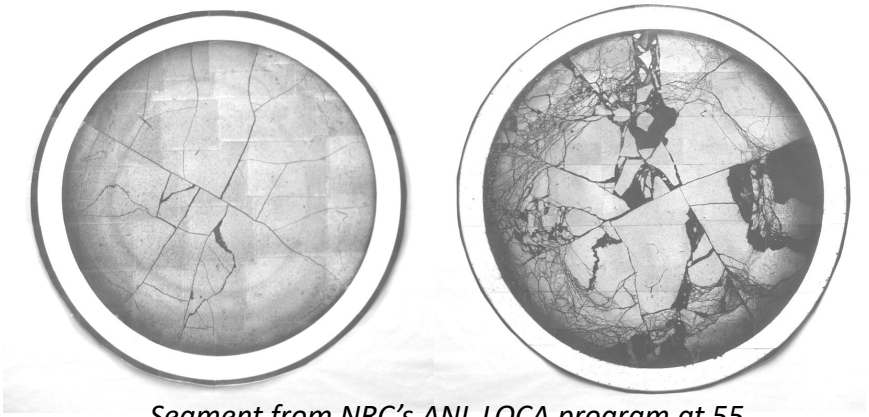




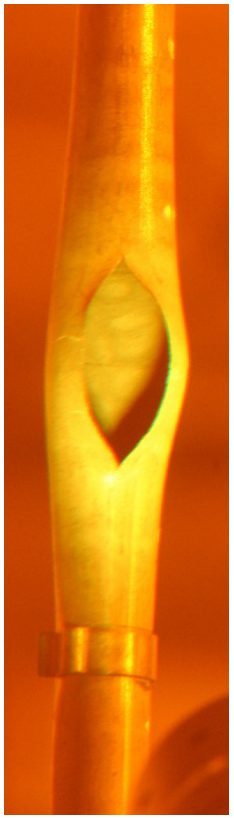
Empirical limits are derived in such a way to be independent of any experimental non-prototypicalities.

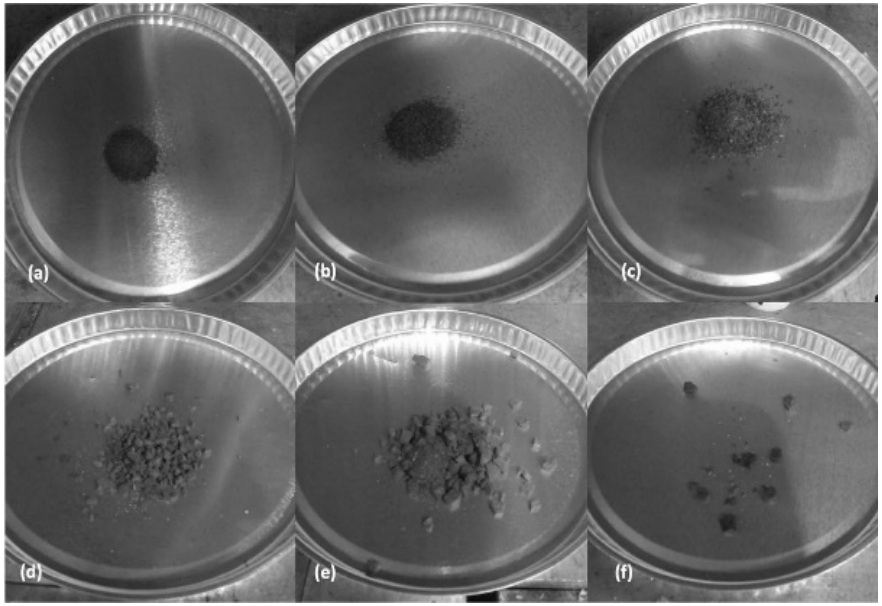
Outcome of the RIL:
Identify when FFRD occurs

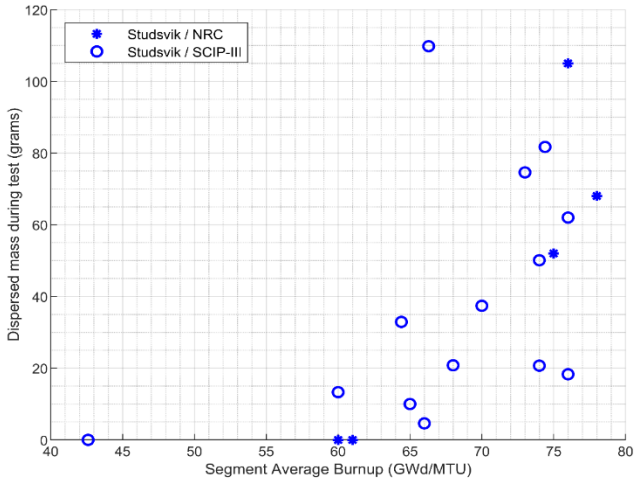




Segment from NRC's ANL LOCA program at 55 GWd/MTU before and after testing





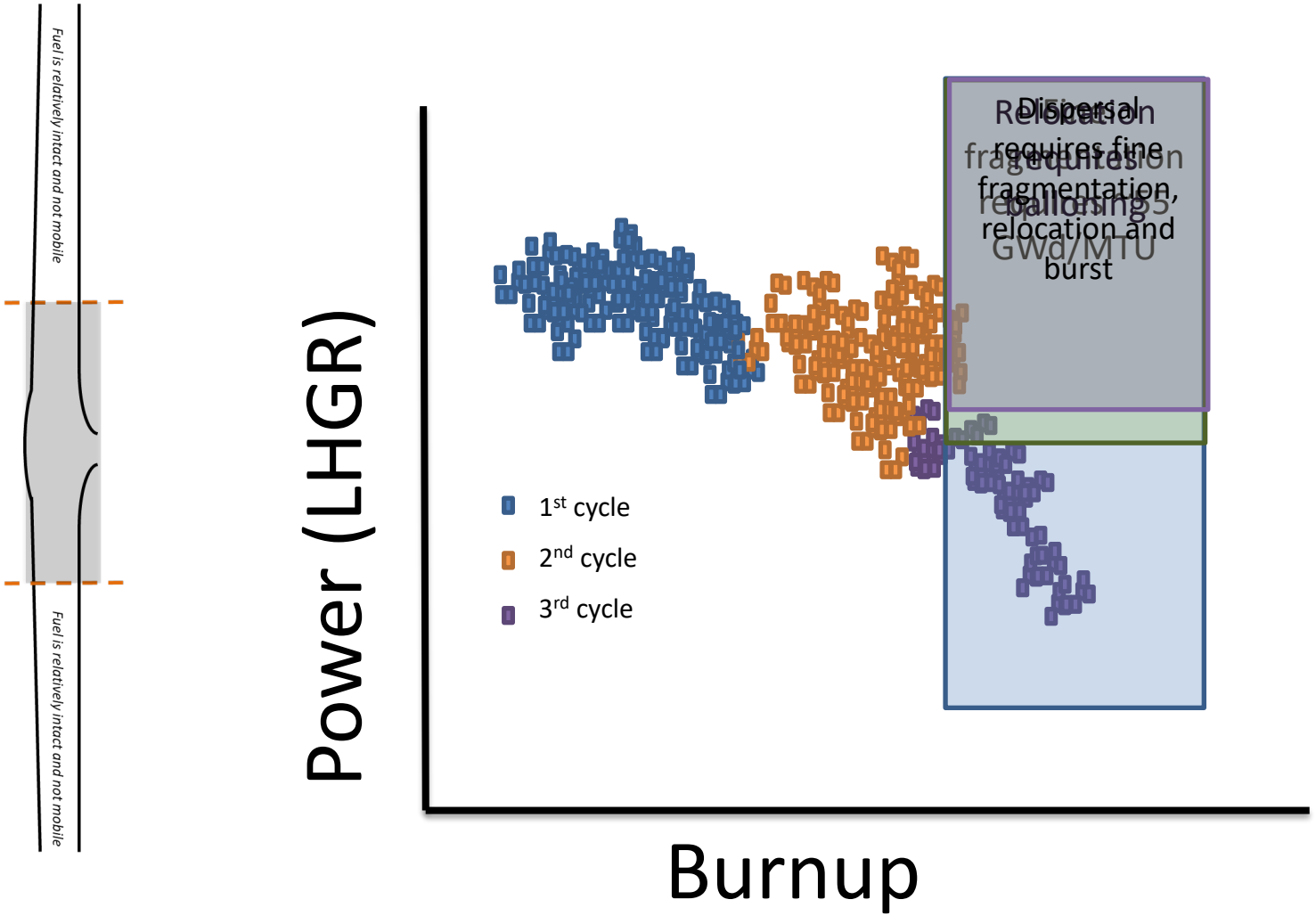


Outcome of the RIL:
Identify when FFRD occurs

Address five elements of the RES staff's interpretation of FFRD research and describe the technical basis for these elements:

1. Fine fragmentation threshold
2. Fuel relocation threshold
3. Model to quantify dispersal
4. Document *transient* fission gas release
5. Quantify packing fractions in the balloon region

Outcome of the RIL:
Identify which rods are a concern for FFRD

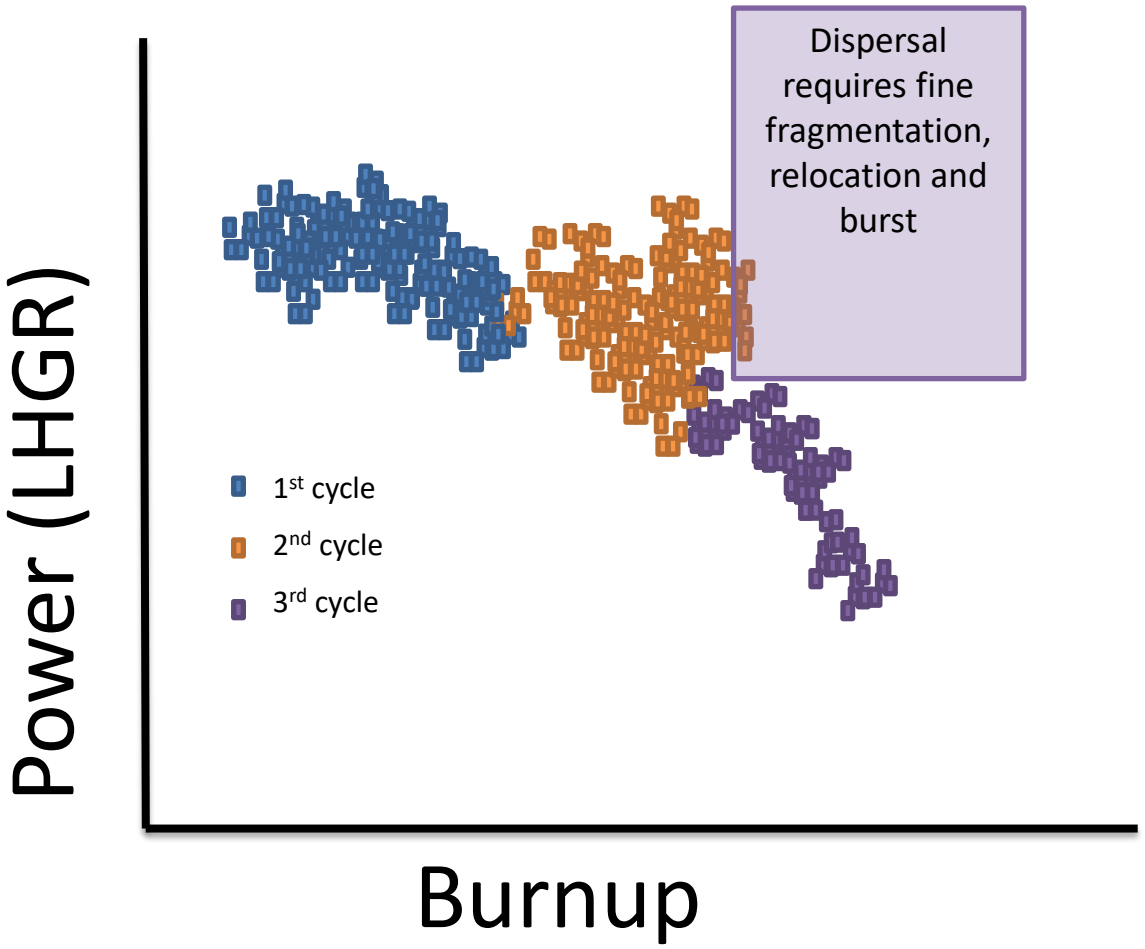


For the **dispersal** zone, some core loadings may result in no region of overlap

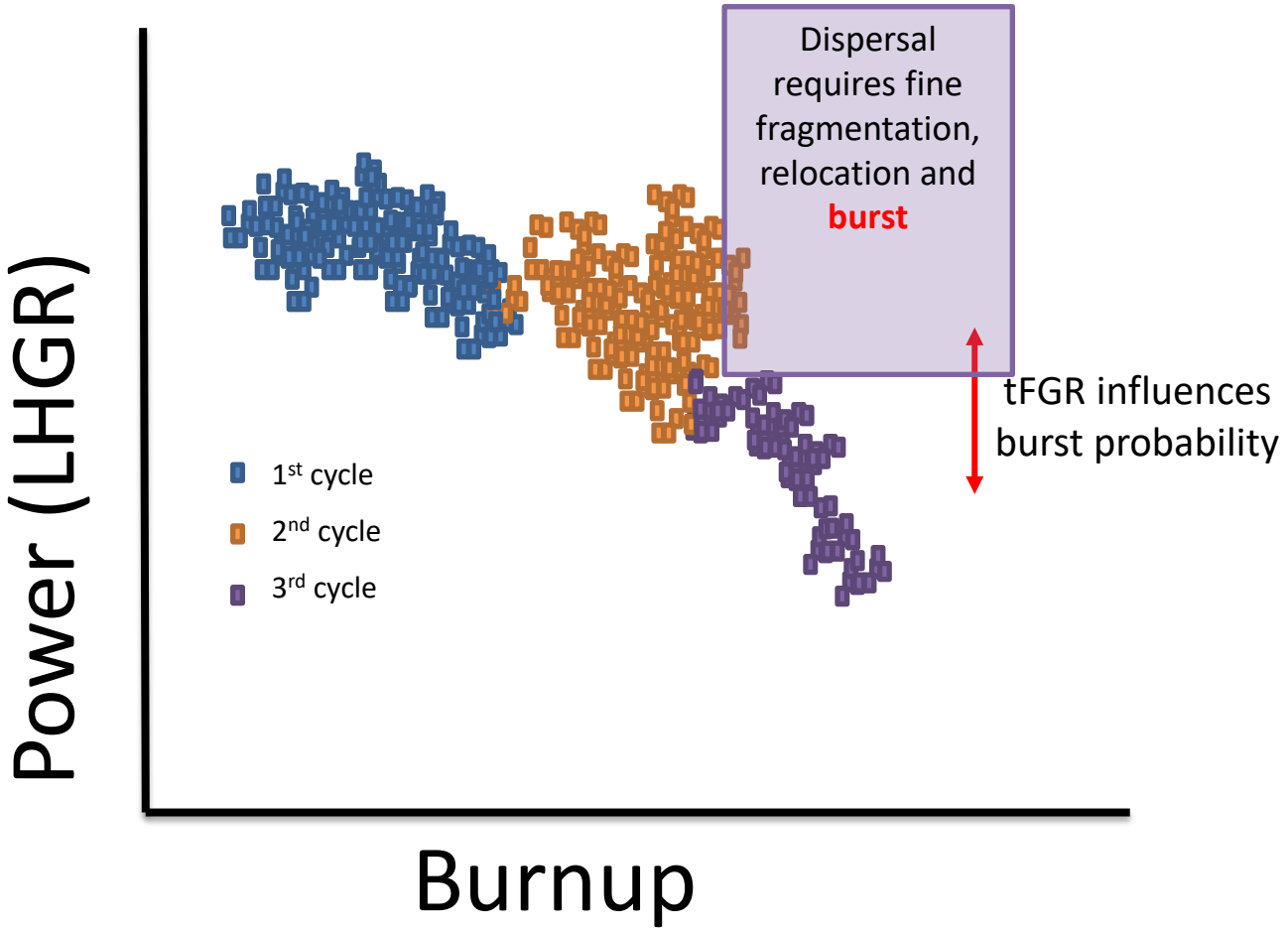
Overlap influenced by:

- ECCS response
- Plant design
- Loading pattern
- Fuel and cladding design

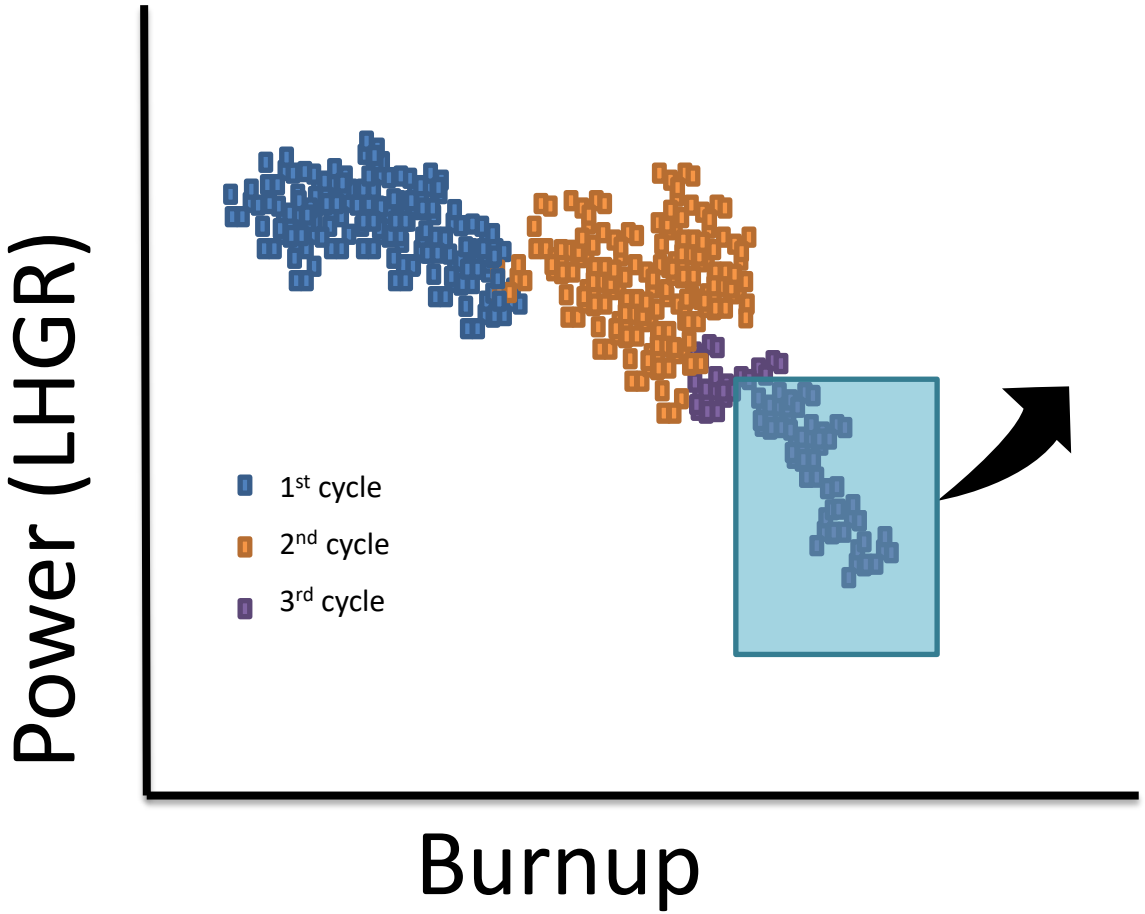
This information is prototypical of PWR. BWR's will have few if any rods susceptible to dispersal due to different operating practices, system pressure, etc.

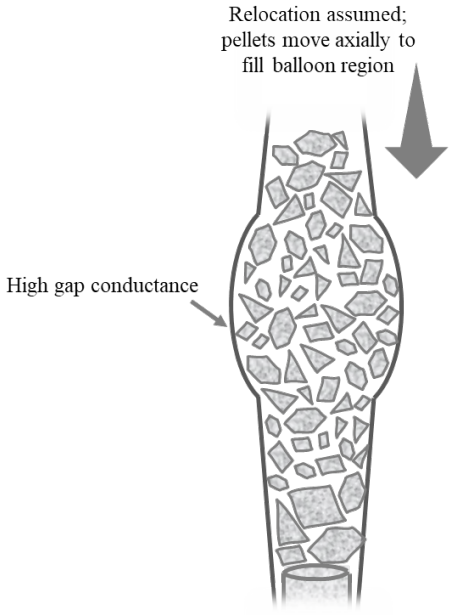


Transient Fission Gas Release - Increasingly important at higher burnup; Important to accurately predict burst



Relocation **packing fraction** - Important to accurately predict burst and peak temperature for non-burst high burnup rods





Assume the balloon region is 70-85% fuel (15-30% void) by volume for calculating rod behavior

The RIL supports targeted FFRD analysis

- Fine fragmentation
  - Not seen below 55 GWd/MTU
- Fuel axial relocation
  - Not seen in cladding with less than 3% strain
- Fuel dispersal
  - Fine fragmentation and relocation are prerequisites; Therefore, dispersal requires burnup > 55 GWd/MTU, strain > 3%
  - Doesn’t happen unless there’s rupture
- Transient Fission Gas Release
  - Increasingly important at higher burnup
- Relocation packing fraction
  - Important for non-burst high burnup rods

This presentation will address…

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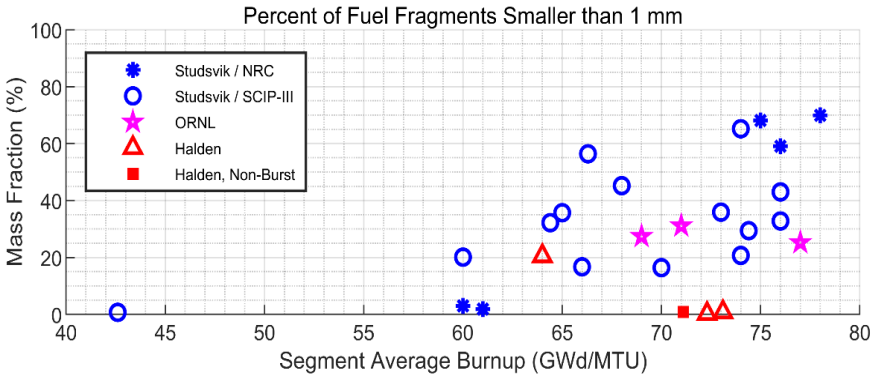
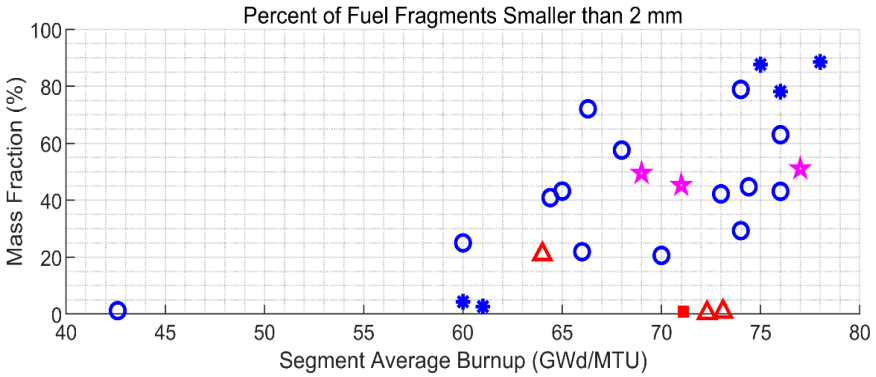
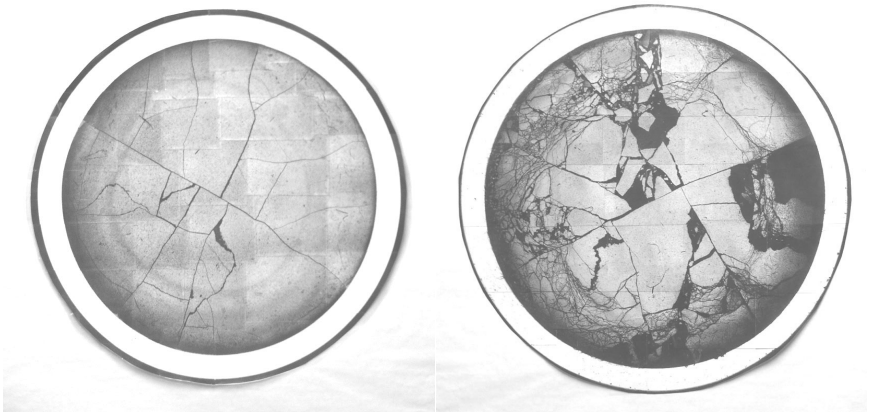
The basis for empirical thresholds included in the RIL

Other Matters

Element 1: Empirical threshold at which fuel pellets become susceptible to fine fragmentation





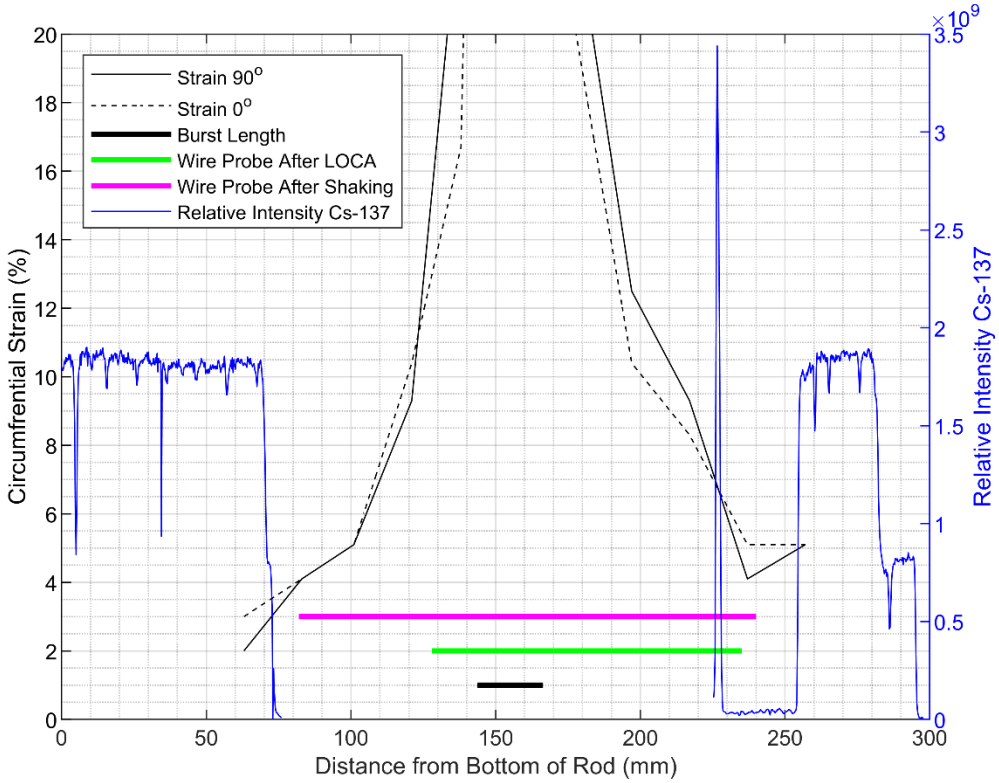


Segment from NRC's ANL LOCA program at 55 GWd/MTU before and after testing

Research supports a pellet-average burnup limit of **55 GWd/MTU** as the **onset of fine fuel fragmentation**

FFRD

Element 2: A local cladding strain threshold below which relocation is limited



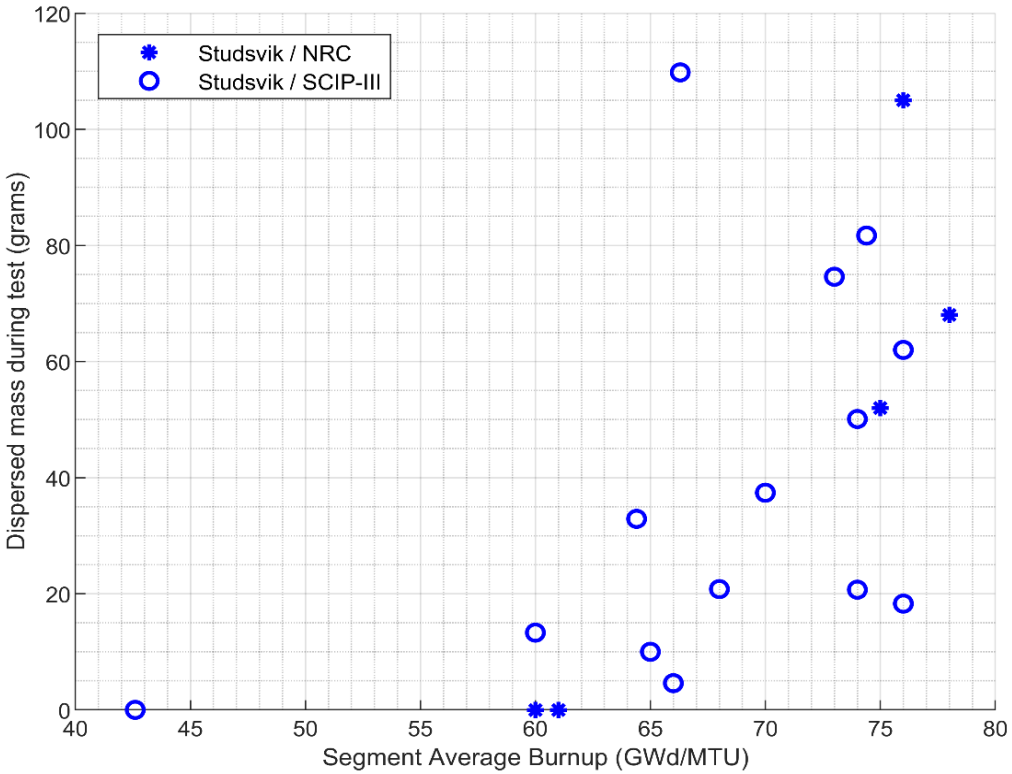
NRC test #	Strain threshold, top (%)	Strain threshold, bottom (%)
189	6.0	3.0
191	6.0	4.0
192	5.0	4.0
193	1.0	4.0
196	3.0	5.0
198	4.5	9.0

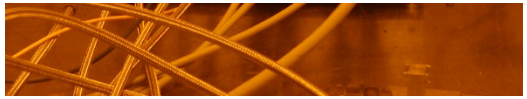
Research suggests **fuel relocation is limited** in regions of the fuel rod experiencing **less than 3% cladding strain**.

FFRD

Element 3: A conservative value for the mass of "dispersible" fuel as a function of burnup

What do dispersal measurements look like?





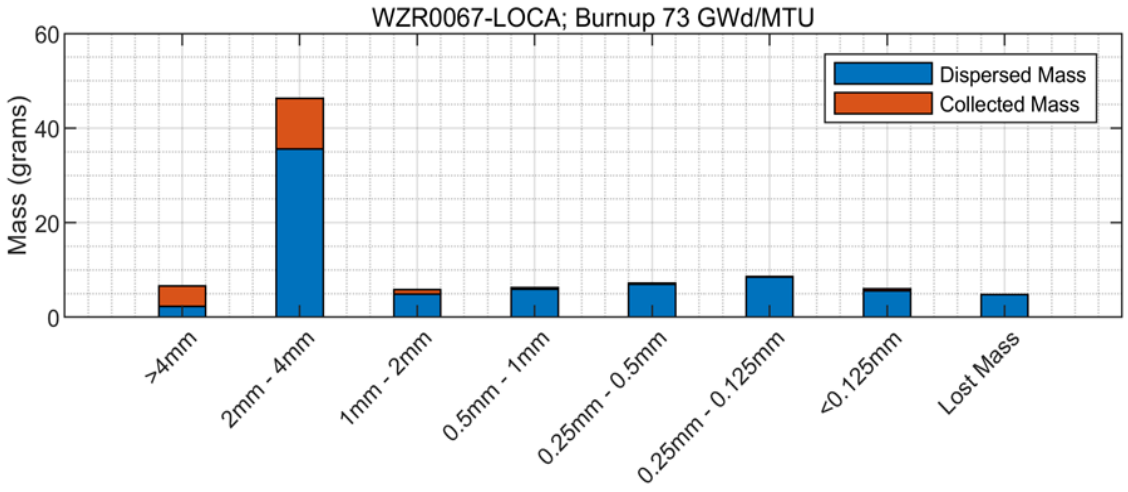
Dispersal "during the test"

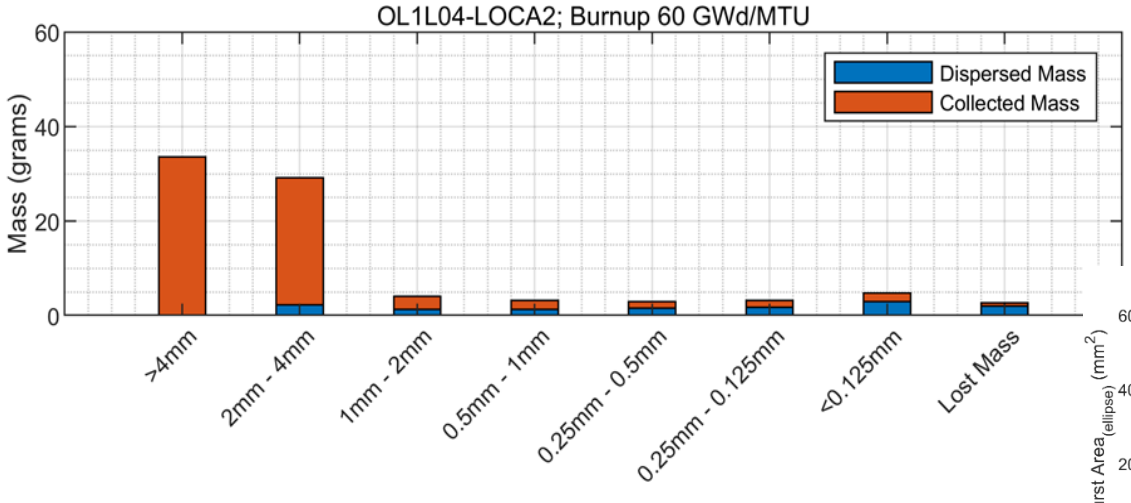
Element 3: A conservative value for the mass of “dispersible” fuel as a function of burnup

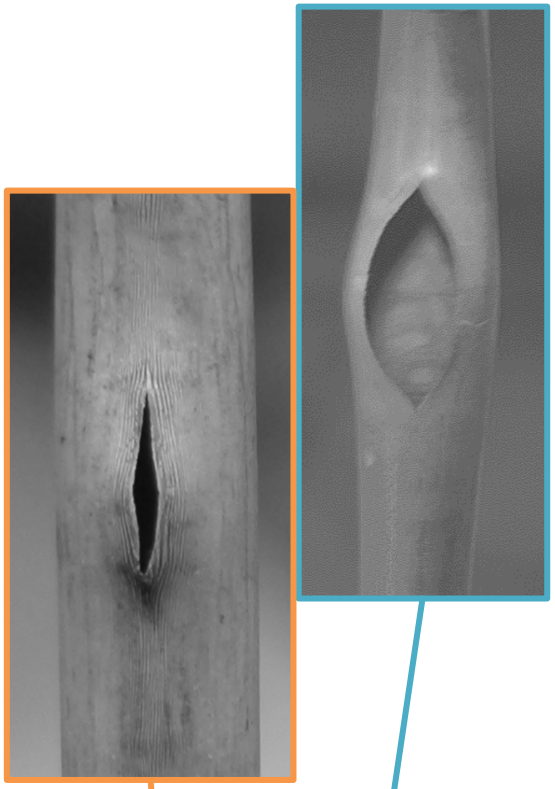
What do dispersal measurements look like?

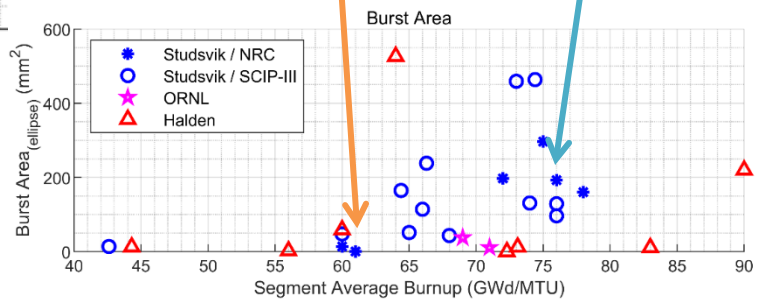
Dispersal “during shaking”

Element 3: A conservative value for the mass of "dispersible" fuel as a function of burnup



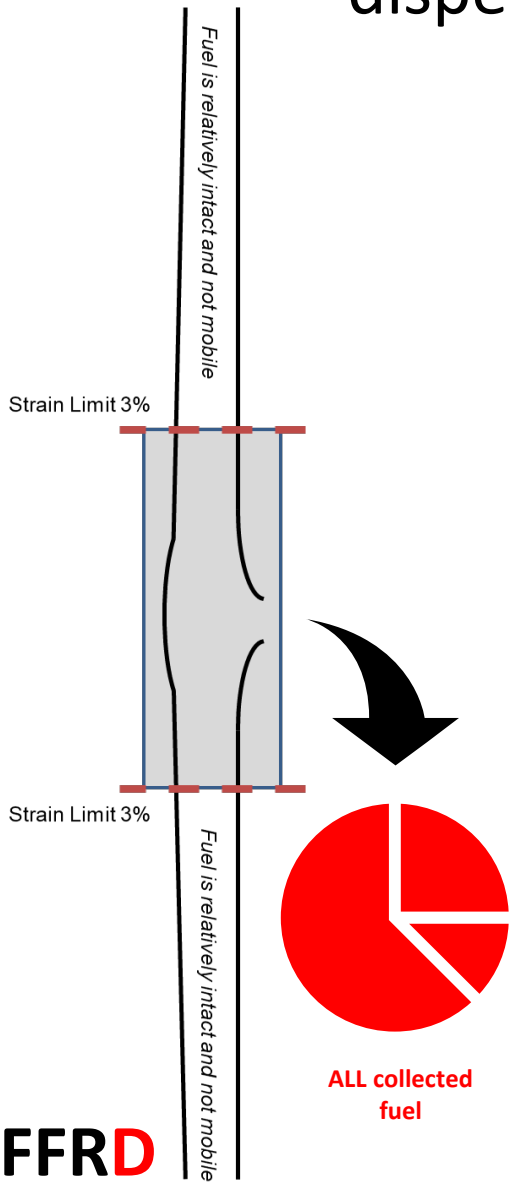






FFRD

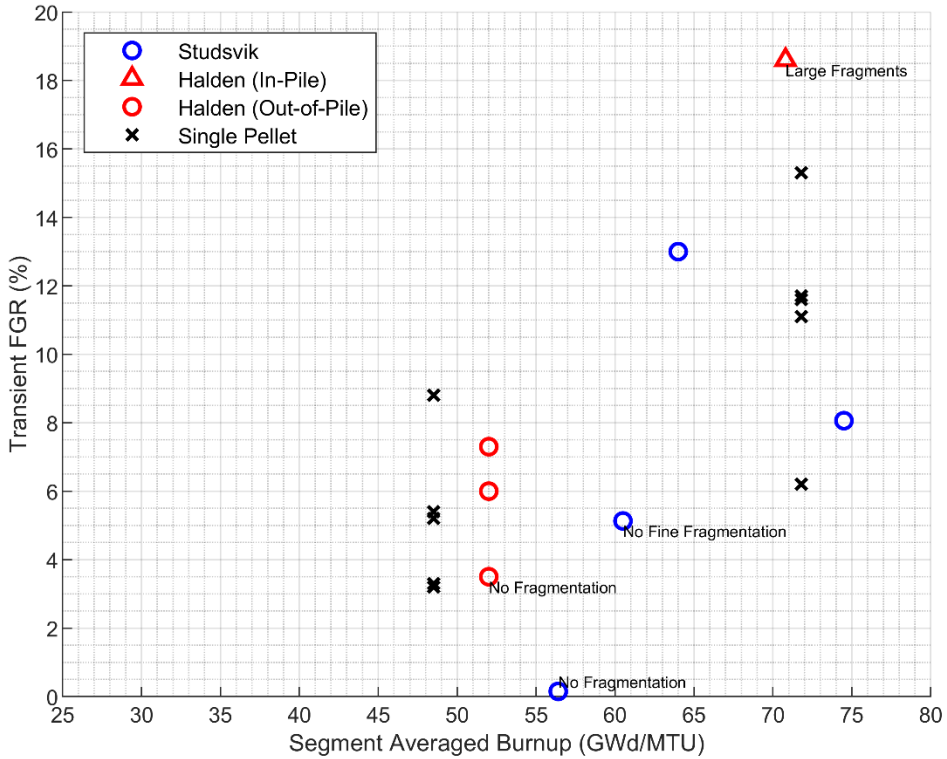
Element 3: A conservative value for the mass of "dispersible" fuel as a function of burnup



	Difference between dispersal predicted by the model and all mobile fuel observed in the experiment	
SCIP test	Mass (g)	Prediction/Measured
OL1L04-LOCA-2	125	250%
N05-LOCA	-19	76%
VUR1-LOCA-1	15	109%
WZR0067-LOCA	-16	83%
VUL2-LOCA1	-7	94%
VUL2-LOCA3	8	105%
VUL2-LOCA4	5	102%

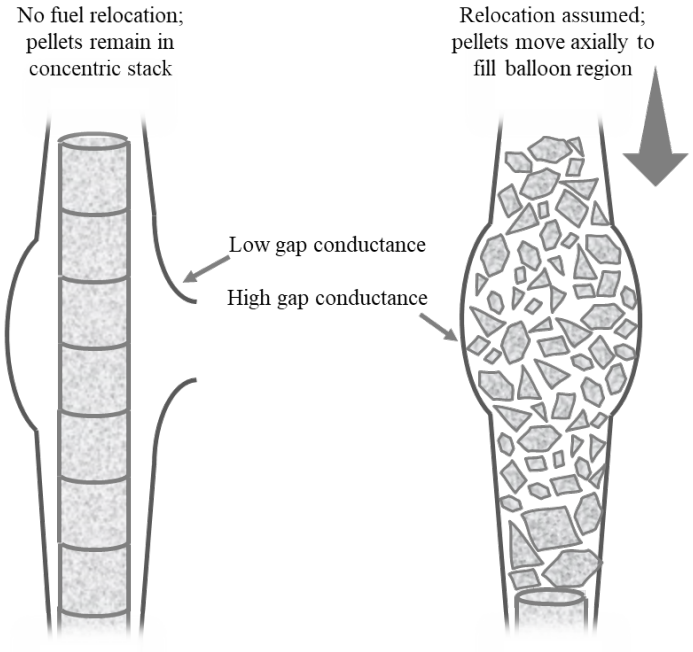
Recommend a model to predict the mass of fuel dispersal to be all fuel above the **burnup threshold of 55 GWd/MTU** in the length of the rod with **greater than 3% cladding strain** to disperse.

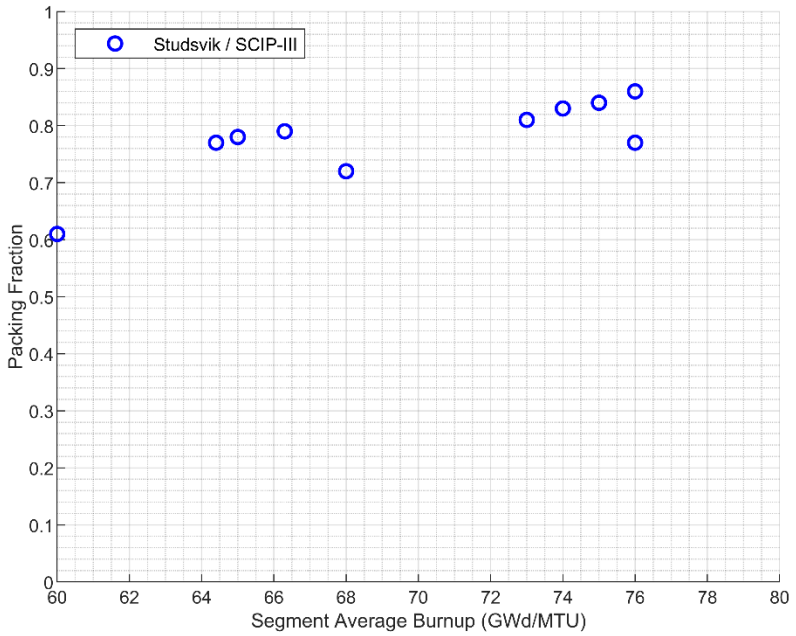
Element 4: Provide evidence of significant tFGR that may impact ballooning and burst behavior of high burnup fuel under LOCA conditions



Data shows increasing transient fission gas release with burnup. However, many other factors besides burnup impact tFGR (e.g., fuel temperature, stresses in fuel). Licensees will need to address tFGR in their LOCA evaluation models. Some models exist for tFGR, but more validation of those models is needed.

Element 5: Establish a value for the packing fraction of relocated but non-dispersed fuel in the balloon region





It is reasonable to use packing fraction values between 70 to 85 percent for fuel susceptible to fine fragmentation. (Fuel at lower burnup would likely have a lower packing fraction).

To determine the impact on ballooning and burst, it is important to examine a range of packing fractions to account for these effects.

FFRD

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Other Matters

Discussion of Consequences and Consequence Modeling

- Refers to SECY-15-0148 and NUREG-2121
- Reiterates potential safety concerns associated with FFRD:
  - energetic fuel-coolant interactions
  - recriticality of dispersed fragments
  - core coolability and long-term decay heat removal
  - radiological impacts, including control room dose and equipment qualification*

** Being addressed outside of the RIL, as part of an update to Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors."*

Limitations of the Empirical Database

- Limits are not applicable to doped fuel or coated cladding.
  - Additional research could demonstrate that the limits in the RIL apply or are bounding
  - Note doped fuels have different FGR behavior, so it would be important to understand implications on FFRD
  - Note coated claddings have been shown to have less strain and smaller burst openings, which could mean better performance with respect to FFRD

Limitations of the Empirical Database

- Limits are simplistic, derived as a function of burnup only.
  - Burnup is likely a surrogate for more direct variables such as porosity, stresses within the fuel pellet, grain growth and subgrain formation. These features are likely influenced by operating history
  - Additional research to allow for more mechanistic treatment of these variables could allow for refinement of the limits
- Limits anticipate accurate prediction of cladding strain along the axial length of a fuel rod. Burst opening size is presumed to be stochastic and therefore limits assume large opening size.
  - Additional research to validate balloon height, axial strain profile and burst opening could allow for refinement of the limits

What's next?

- Participating in SCIP IV
  - Includes testing of non-standard fuel
  - Additional testing to characterize tFGR
  - Testing in the mid-level burnup range
- Refining analysis tools to improve core-wide FFRD analysis
  - Building from 2015 and MELLLA+ experience
  - Enhancing resolution and realism
  - Utilizing new modeling features

What's next?

- RIL will establish foundation for next steps
  - Industry can build from the RIL based on their licensing needs, justifying design specific limits
  - Researchers can build programs from the RIL that produce the information needed to go further

RIL in context

LOCA initiating event frequency

LOCA cond. 1 | LOCA cond. 2 | LOCA cond. 3 | LOCA cond. 4

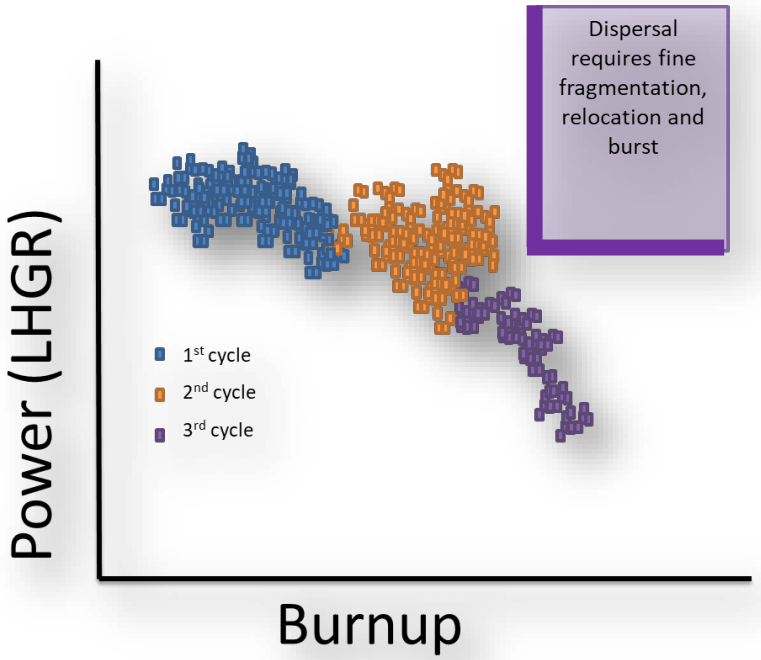
RIL

Fuel response to LOCA conditions

input

System response to dispersed fuel

Comparison of safety analysis to licensing basis




Questions?