Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title: 710TH MEETING, ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

Docket Number: N/A

Location: teleconference

Date: 11-01-2023

Work Order No.: NRC-2589 Pages 1-129

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(202) 234-4433

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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710TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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OPEN SESSION

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WEDNESDAY

NOVEMBER 1, 2023

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The Advisory Committee met in hybrid format, In-Person and via Video-Teleconference, at 8:30 a.m., Joy L. Rempe, Chairman, presiding.

COMMITTEE MEMBERS:

JOY L. REMPE, Chairman

WALTER L. KIRCHNER, Vice Chairman

DAVID A. PETTI, Member-at-Large

RONALD BALLINGER, Member*

CHARLES H. BROWN, JR., Member

VICKI M. BIER, Member

VESNA B. DIMITRIJEVIC, Member

GREGORY H. HALNON, Member

JOSE MARCH-LEUBA, Member
ROBERT P. MARTIN, Member
THOMAS E. ROBERTS, Member
MATTHEW W. SUNSERI, Member*

ACRS CONSULTANT:
DENNIS BLEY
STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:
HOSSEIN NOURBAKHSH

ALSO PRESENT:
SUSAN COOPER, RES*
ALAN KURITZKY, RES

* present via video-teleconference

P R O C E E D I N G S

(8:30 a.m.)

CHAIR REMPE: So, good morning. This meeting will now come to order. This is the first day of the 710th Meeting of the Advisory Committee on Reactor Safeguards.

I'm Joy Rempe, Chairman of the ACRS. Other members in attendance are Ron Ballinger, Vicki Bier, we expect Charles Brown to be joining us soon, Vesna Dimitrijevic, Greg Halnon, Walt Kirchner, Jose March-Leuba, Bob Martin, Dave Petti, Tom Roberts, and Matthew Sunseri. I note we do have a quorum.

Today, the Committee is meeting in person and virtually. The ACRS was established by the Atomic Energy Act and is governed by the Federal Advisory Committee Act. The ACRS section of U.S. NRC public website provides information about the history of this committee and documents such as our charter, bylaws, Federal Register Notices for meetings, letter reports, and transcripts of all full and subcommittee meetings, including all slides presented at the meetings.

The Committee provides its advice on safety matters to the Commission through its publically available letter reports.

The Federal Register Notice announcing

this meeting was published on October 13, 2023.

This announcement provided a meeting agenda as well as instructions for interested parties to submit written comments or request opportunities to address the Committee.

The Designated Federal Officer for today's meeting is Mr. Hossein Nourbakhsh. I guess it's actually Dr. Hossein Nourbakhsh, sorry.

A communications channel has been opened to allow members of the public to monitor the open portions of the meeting. The ACRS is inviting members of the public to use the MS Teams link to view slides and other discussion materials during these open sessions.

The MS Teams link information was placed in the Federal Register Notice and the agenda on the ACRS public website. Periodically, the meeting will be open to accept comments from participants listening to our meeting. Written comments may be forwarded to Dr. Nourbakhsh, today's Designated Federal Officer.

During today's meeting, the Committee will consider the following topic, Level 3 Probabilistic Risk Assessment. We'll also have our planning and procedures session at 1:00 p.m. today.

Note that the public -- the NRC public

meeting website indicates there will be an ACRS planning and procedures subcommittee meeting today at noon.

And that meeting has been cancelled. That is, I mentioned previously, as indicated in the agenda, our full committee planning and procedures meeting will occur at 1:00 p.m.

A transcript of the open portions of the meeting is being kept and it's requested the speakers identify themselves and speak with sufficient clarity and volume so they can be readily heard. Additionally, participants should mute themselves when they're not speaking.

At this time, I have several items of person interest. First, I'd like to acknowledge the many contributions of former Commissioner Forrest J. Remick, who passed on October 9, 2023. Appointed by President George Bush, Dr. Remick became a Commissioner on December 1, 1989. And he served until his term expired on June 30, 1994.

Dr. Remick has the distinction of being the only person to serve the NRC in the multiple roles of an Office Director in the Office of Policy Evaluation, OPE, an Administrative Judge on the Atomic Safety and Licensing Board, Vice Chairman and Chairman of our ACRS, and an NRC Commissioner.

His service as the Director of OPE came during the crucial period after the Three Mile Island Unit 2 accident. And he provided important policy and technical advice to the Commission.

And a different type of note, I am happy to announce that Ms. Andreas Torres is joining the ACRS as a Senior Program Analyst of the PMDA Branch.

Many of you remember Andreas because of the assistance she provided when she was completing a rotational assignment with ACRS this year. In particular, her assistance with our international regulatory advisory committee outreach activity was valuable during this rotation.

What you may not know are her excellent credentials, which include over a decade of service with the U.S. NRC and a Master of Science in program management from George Washington University. So, I hope you'll join me in officially welcoming her back to ACRS on a permanent basis.

And third, I'm happy to announce that Rob Kirsch is joining ACRS as the Technical Assistant. Rob has over 30 years of experience in the nuclear field, including power and non-power reactors, fuel cycle, radioactive materials, and decommissioning.

Since 2014, he served as Commissioner Baran's technical assistant for reactors.

Prior to that time, he served as Commissioner Magwood's technical assistant for reactors, Chairman Klein's technical assistant for both materials and reactors, and 18 years, he served in NRC's Region III Office.

So, I hope you'll join me in officially welcoming Rob to joining us.

So, at this time, I'd like to ask other members if they have any opening remarks?

Hearing none, I'd like to ask Vesna Dimitrijevic to join -- to lead us in our first topic for today's meeting. Vesna?

MEMBER DIMITRIJEVIC: Yes, good morning.

Can you hear me well?

CHAIR REMPE: We can.

MEMBER DIMITRIJEVIC: Okay, all right, good morning. So, I would like to invite Alan, and I think, Susan Cooper, Alan Kuritzky and Susan Cooper to give us the presentation on the Level 3 PRA project for Volumes 3 and 4.

Just to continue the discussion which we had at our staff committee meeting and some questions which we have brought up in this meeting on the, you know, the low -- early fatality frequencies on the human actions after the core melts.

So, Alan and Susan, or Susan, I don't know who's going to begin. Please take it over.

MR. KURITZKY: Thank you very much, Dr. Dimitrijevic. This is Alan Kuritzky from the Office of Research. And I am the project program leader for the Level 3 PRA project.

And as Dr. Dimitrijevic had mentioned from -- that we had a meeting -- a subcommittee meeting from October 19th. And this is kind of a somewhat of a continuation of that meeting.

I'll try not to retread too much ground, but a little bit of information with the last meeting, I'll recap just to kind of bring everybody up to speed if you weren't there on the 19th.

I'd also like to express my appreciation to all the members here for their time. I know you're very busy with lots of new reactors, advanced reactor stuff, and we've got to shoe horn us other projects in where you can. So, I do appreciate the commitment of time and your attention for today's meeting.

I also want to acknowledge, that while I'm speaking up here, I'm talking about work in Volumes 3 and 4 that was performed by many, many technical experts in the agency as well as are at National Lab and commercial contractors.

And while I can't name all of them since there were so many of them, I do suggest people look at the title pages and reports in the acknowledgment sections and see all the wonderful experts that we have either in house or contractors that have contributed to this work.

And I appreciate all the effort they've put into this project. So, they're really supported me tremendously.

So, I also want to mention that I'll be presenting most of the slides in today's presentation. But as Dr. Dimitrijevic had mentioned, Susan Cooper will be presenting some information on the Level 2 PRA human reliability analysis. So, when we get to those slides, I'll pass it off to her. She is not here in person. She works remotely from Delaware. And so she will tie in at the appropriate time.

With that, if we can go on to the next slide, please? Just a quick outline of what we're going to talk about today. And again, like I said, this is on the Volumes 3 and 4 of the Level 3 PRA project that we are kind of focusing on some particular issues that were follow on to the subcommittee meeting back on October 19th.

I will, again, give a quick background of the work and some very brief summary results, not the detail level we did last time.

And then, focus primarily on some insights and the parameter and modeling on certainty and how it was treated in this project as well as the Level 2 HRA, the post-core damage HRA that Dr. Cooper will talk about.

Next slide, please? Okay, so, just very quickly, this project was kicked off back in 2011 with the staff's requirements memorandum came out in response to SECY-11-0089.

That directed the staff to do a complete full scope Level 3 PRA project. And that means that, not just are we looking at the two reactor cores on site, we're also looking at spent fuel in both the spent fuel pools and through dry cask storage.

We're also looking at all reactor modes of operations, so not just full power, but also low power and shutdown. And we're looking at all hazards to prevent damage from fires type of events, high winds, et cetera, everything except for intentional sabotage, security related events are out of scope.

And we're also, by the way, looking at

things, not only individually in terms of each radiological source on site, but also in an integrated fashion.

We have a task to look at the impact and the effect of having an accident in one radiological source on site like a reactor or spent fuel pool and the response to a potential accident at one of the other sources.

The reference plant for the site, or the -- excuse me, the reference site for the project is a two-unit Westinghouse Pressurized Water Reactor with large dry containments.

And many of the insights and things that we derive and information we derive from this project is directly applicable to that reference site, but there are other things that might be more applicable to similar type plants or other PWRs of the fleet as a whole when it comes to maybe possibly some of the consequences of information.

Next slide, please? Okay, so, just to quickly to put everybody in context, we're going to produce off of this work and it's going to be released publically, and it's eight volumes which consist of probably around 20 reports, maybe slightly over 20 reports.

The different volumes are shown on this graphic. Summary Volume 1 up in the upper left hand corner, that's the one that's going to capture the high level insights and results, perspectives, comparisons to other studies, et cetera.

Once that gets published at the end of the project, that's probably the volume that's going to get the most eyeballs going forward. So, there's a lot of work that will go into that volume.

Volume 2, the background volume includes a description of the reference site and plant. It also discusses at a high level the technical approach to the various parts of the study as well as just some general background information on the project.

Volume 3 through 8 involve all the technical material.

Volume 3 which was released publically for comment back in April of 2022 covers the reactor at power, internal events, and floods. It includes volumes from the Level 1 PRA for both internal events and Level 1 PRA for internal floods.

And then it has volumes for the Level 2 and 3 where the internal events and floods are combined because internal floods make such a small contribution, it didn't make sense to do a Level 2 and

3 reports for them separately.

And then, lastly, includes an overview volume. That was something that came about when we first were presenting the preliminary public -- preliminary results to senior management back in 2018. Because this study had a cutoff date of August 2012, and it was many years later, and there were significant changes in plant equipment and procedures since that time, it was felt that we should probably do something to reflect what that impact would be.

Particularly, we're talking about the limitation of FLEX strategies and mitigation strategies as well as they also implemented or installed the new path to shutdown seal to the reactor coolant pools.

Both of those were believed to have significant impact on the risk profile. And so, we thought that we wanted to at least capture what the potential impact would be.

It would have been too much work to try and redo the whole study from the beginning, incorporating those elements. But we want to do a section to be studied where we actually saw what the impact was and wanted to focus to some extent on those results as they were more representative of a current plant operation design.

So, that is all summarized into the overview report. And then, that Volume 3 set of reports and Volume 2, as I said, were released for public comment in April 2022.

We've since addressed their comments. And those reports -- the Volume 3 reports are with publications right now with the administration for final Office of Administration for final publication.

Volume 2, we're holding back because it references all the other reports. So, we can't really tie up the references to that until the rest of the reports are done, too. So, it will get actually published when we publish Volume 1 at the end.

Volume 4, which is the other volume that's a topic of today's meeting, is the background power for internal fires and external hazards. We have actually quantified the risk of internal fires from seismic events and from high winds.

We have done a qualitative semi-quantitative screening analysis for other hazards. And for those similar to Volume 3, the Level 1 reports for fire, seismic, and wind are in separate volumes.

We also, in Volume 4, see for the high wind, we combined the other hazard tree analysis so there's a Part 1 and Part 2 to that. And for Level 2 and 3, we have one combined volume for each of those PRA levels that cover fire, seismic, and wind.

But unlike Volume 3 where the internal flood isn't particularly called out separately, Volumes 4D and 4E, there actually are separate sections everywhere that we talk about the fire, we talk about results for seismic, we talk about results for wind all separately.

Next slide, please? And then the other volumes that are listed here to still come out in public comment, Volumes 5 through 8 and including Volume 1, will all come out sometime in 2024, calendar year 2024.

Those dates in there are in gray because they demonstrate some level of uncertainty for any project deliverable that's more than a few months out because the availability of key personnel is very uncertain.

Next slide, please? This is a table that we showed back at the ACRS subcommittee meeting. It just gives a high level summary of some of the key risk metric results.

Again, the more detailed stuff is included in background slides for this presentation since we discussed it at fairly length -- at fair length in the subcommittee meeting.

But just as a quick recap, we look at the first rows of the table, you see core damage frequency and large related release frequency which are two of the surrogate risk measures that are used most heavily by the NRC.

And we can see that the results, particularly if you're looking at the last comp of the 2020 FLEX case, you can see that we're fairly -- that we're below those risk metrics, but not with a huge margin.

Whereas, if you look at the last two rows which are the two risk metrics that are associated with the Commission's safety goal policy statement, the two quantitative health objects, that's individual early fatality risk and individual latent cancer fatality risk, you can see there by the green numbers that there's quite substantial margin between the risk that we estimated in the 2020 FLEX case and what the QHO metric is.

MEMBER MARCH-LEUBA: Can I interrupt you for just a --

MR. KURITZKY: Yes.

MEMBER MARCH-LEUBA: I wanted to ask you

at the end of my question whether you think that the Level 3 expense of the formula Level 3 PRAs worth it? Okay?

Let me tell you where I'm going. Level 3 is obviously the best testing that we have of those green numbers, given the assumptions. But it gets very expensive and possibly and long -- is this the wrong microphone again?

(Off-microphone comments.)

MEMBER MARCH-LEUBA: Okay. So, where was I going? Yes. What do you gain by spending all this money on a Level 3 that you don't have with a Level 2? Is it worth it?

If it was your money and you were designing a new reactor and they tell you, now you have to spend three years and $10 million doing your Level 3 and you're stuck in Level 2.

MR. KURITZKY: Okay, thank you for that question. I have to say that the actual answer to that question is probably above my pay grade. But my experience with this project, and one of the objectives of the project, by the way, was to get an idea of the cost and effort to do a Level 3 PRA.

Because I think when this project was first envisioned, the Commission at the time, the

Chairman at the time and one of the Commissioners, were probably thinking, you know, is this something we want to have the industry go ahead and do Level 3 PRAs or either the existing fleet or for the new reactors.

And I think since the Commission has turned over quite a bit since then, I don't think the push is there anymore.

So, I would say -- and so, we're going to have a section in the summary report that addresses what we found out about that. It's going to be somewhat limited in its utility because, one thing we have discovered, we'll probably do it from the beginning if we really thought about, is that doing a Level 3 PRA is very case specific.

It's very much dependent on what's the quality and completeness of the Level 1 and/or Level 2 studies that the site has. Okay, that's very important.

What scope is involved? Are we looking just at internal events and internal floods? Are we looking at other hazards? Okay, that becomes very important contributor to the scope.

Again, in our case, we're looking other hazards, I mean, other radiological sources besides just the reactors. That's another complication.

Even for just a reactor, besides what level of PRA has already been completed and the quality of that PRA are the people that did that PRA, are they still available?

The people that did the Level 1 and 2 PRAs are available to support the Level 3 PRA, that is a much more efficient approach than for bringing in new people that, you know, those people have long since disappeared or they were contractors that are now not available. And now, you're kind of starting from the beginning.

So, there is a tremendous amount of variability based on several factors. In our case, in particular, another major objective of the project was to increase the level of PRA capabilities with the staff. We are a risk-informed organization and we want to become more risk-informed as we go forward.

And so, it's necessary that we have a sufficient stable of experienced PRA analysts here to be able to handle all the potential applications that are risk-informed, et cetera, and the projects that might be risk -- involve a quantification of risk.

So, we have made a focus of bringing up a lot of junior and mid-level people and bringing them up into more experienced ranks with the PRA, all levels of the PRA. Because of that, we -- I think we've succeeded very well in that and that we really a lot of people and they have greatly increased their PRA capabilities.

But because of that, the level of effort, compared to just bringing in a high powered consulting firm who can sit there and crunch out your Level 3 PRAs, that'd be totally different.

So, again --

MEMBER MARCH-LEUBA: I'm not questioning why you're getting out of CDF, I mean, obviously, a training -- I guess the training is worth it?

The question I'm posing myself, I'm a bank and you're designing a new reactor. And you come with your Level 2 PRA results with have a magenta ones in the table, saying that satisfies the requirements. Now, give me $10 million so I can do the green ones.

Try to convince me why it's worth it.

MR. KURITZKY: So, again, what I was getting at, I wasn't trying to sell the advantage of the project, but the point is that, the estimate, what the cost is, we don't have -- our estimates of what the cost would be would not be the same as the one that the bank is going to find.

So, the reality is, whether it's worth it or not, you know, depends on how much it costs, which I'll try to give you an idea, we're not going to know exactly how much it would cost someone else to do it. But the benefits -- we've seen quite a few benefits from doing the full Level 3.

We've learned a lot of interesting things. There's some good insights in there. We've also identified quite a few uncertainties that need to be addressed, again, underlying the need to be risk-informed, not risk-based, of course. But whether it's worth it or not, that trade off, you know, that's a good question.

The comments that we've received from NEI on both Volumes 3 and Volume 4 have been focused along those lines. Saying, hey, we don't see the value in going forward and doing the full, for the operating fleet, you know, the existing -- the new reactors, advanced reactors, that's a different policy decision. But they believed it wasn't worth it.

I don't know, I think there was a lot of value in doing one to kind of see what those insights are. Are you going to get incrementally enough value from doing other ones to make it worth the cost? I can't give you a definitive answer on that. Again, it depends on how much it costs.

So, I believe there are benefits from it, whether they justify the cost, I would not would do. I certainly would not state, yes, definitely. That I will not say.

But can say, that it's not even.

MEMBER MARCH-LEUBA: Right, the bank is the one that decides the cost benefit?

MR. KURITZKY: Right.

MEMBER MARCH-LEUBA: And the regulator comes in, well, I don't care what your cost is, you have to do it.

MR. KURITZKY: Adequate protection.

MEMBER MARCH-LEUBA: I just wanted to put the concept here on the record. Because whenever we have people sitting in the back of the room which are the Applicants, they all say, woo, this is too expensive. And more than expensive is the time delay. Because I am designing a new reactor, I don't have time to do this.

MEMBER BIER: I have a couple of comments and questions related to Jose's point.

First of all, I agree that $10 million sounds like an awful lot. And I don't believe that's what it would cost a licensee to do that's on their own design.

I mean, it's a long time since I've know the cost of PRA first hand, but years ago, it was $2 million for the entire thing, including Level 3. So, things may have changed a lot since then.

But the other question that I had for you, Alan, is sort of for the NRC's purposes in doing this, not whether industry should do it, but regarding the NRC's projects, it seems like there is sort of multiple objectives or multiple benefits of the project.

One is, maybe plant insights, as you said, although some of those may be very plant specific or location specific.

Some of it is methodology like codifying is this an acceptable methodology for industry to use in doing this? Some of it is just internal like, you need more people inside NRC who know how to do Level 3 and how to interpret it, et cetera.

What do you see as the biggest advantages of having gone through this whole effort?

MR. KURITZKY: Okay, thank you, Dr. Bier. So, I would say, again, it's kind of preliminary for calling out, but from my personal opinion so far, I think the biggest benefit has been the fact that the NRC now has staff and even contractors that are much more familiar and experienced with dealing with PRAs.

So, whatever issue should come up, whether it be for a existing reactor or a new or advanced reactor, we're in a much better position to deal with those issues from a risk-informed perspective.

So that one, to me, is probably one of the biggest benefits. I think we also discovered some new insights that differ a little bit from NUREG-1150, which was the last major NRC sponsored Level 3 PRA project, which most of the work was in the late '80s for that and was published in 1990.

But there is, I think, we have discovered there's been a number of advances, a number of things. But honestly, post-9/11, the vulnerability studies, when we were doing those, there was some things that we discovered because, by that time, we had more advanced modeling, advanced tools for modeling through acts of aggression which impacted the timing of core damage, and which then -- which leads to the timing -- or not enough time available to take protective action.

So, that, I think helped refocus our attention on what are the biggest risk drivers? So, I think that there were definitely things that we learned from the study that will benefit the agency in all kinds of ways in the risk-informed arena.

You know, as Dr. March-Leuba said, would the bank bankroll another one? That, I don't know. You know, again, the cost would be a lot less, as you said, the cost would be way less than what we said. But would it even -- still, would it be too expensive to warrant the incremental benefit you'd get from doing one? I can't weigh in on that.

But I do think that we did learn a number of very interesting things. As you can see, even the difference between what the risk term, in fact, have been used in the NRC risk-informed program, CDF and LERF, you know, core damage frequency and large early release frequency as compared to what are the margins with some of these risk metrics we took with those associated with the quantitative health objectives is a different story.

And what you -- how you want to use that, what you want to make of that, that's other people and other pay grades, but I mean, there is some very interesting information that we've

MEMBER PETTI: Will that be captured? I have this question about comparisons to 1150.

Are you planning to do that in the first volume?

MR. KURITZKY: We -- yes, in the Volume 1, we're hoping to have a section where we look at NUREG-1150 and make some comparisons. I think some of the -- we've already been, to some extent, looking into that.

Dr. Keith Compton who is our lead for the Level 3 PRA consequence analysis, Level 3 PRA incremental will have the whole Level 3 piece has been looking some of the information on NUREG-1150.

It's a little bit difficult, I think, my initial understanding from Keith is that sometimes it's a little difficult to make the comparisons, to dig out exactly how things were done in NUREG-1150.

But we already are looking into those to some extent and seeing where, you know, why are we getting certain results different than they did? And that is going to be a focus for the summary volume.

MEMBER PETTI: Good, okay.

MEMBER HALNON: Alan, I'd like to get one question out of the way in my mind, maybe it's an easy answer, maybe it's not.

I'm not a mathematician, I'm an operator. So, I'm looking at this graph, I'm an operator, when can zero be zero? I mean, I see a 10 to the minus 13, that's getting into a world that operators don't deal with.

When is zero zero?

MR. KURITZKY: So, I understand, you're uncomfortable with the number 10 to the minus 12.

MEMBER HALNON: Anything greater than all the zeros on the other side of the --

MR. KURITZKY: So, yes, good comment. So, the idea here, in fact, the summary table for this that's in the actual overview part doesn't even have those numbers as dashes or zeros. I think it says, as zero --

MEMBER HALNON: Okay, so when do the numbers turn into dashes?

MR. KURITZKY: So, these -- and then there's a footnote that says if somebody wants to know the number, somebody in the real world may not care whether 10 to the minus 8, 10 to the minus 12, 10 to the minus 13, it's something they're not going to deal with.

But it's important from a risk quantification because it's the nature of what the metric is you're looking at.

And in this particular thing, it's population weighted. So, therefore, you have a very low number defined by the population.

There's a number of reasons why that number's so low and I'm going to get into that when we go into our future slides. But --

MEMBER HALNON: If you want me to indulge in extremely low numbers, I know nothing would -- that aren't meaningful, that's fine.

What I just wanted to know is, is that 10 to the minus 13th and the next one 10 to the minus 8, is that a significant difference?

In mathematics space, you're going to say yes. In reality, is it?

MR. KURITZKY: Yes, I believe it is.

MEMBER HALNON: Okay. So, I'm going to listen throughout this to hear that reality. I don't, you know, if all I hear is mathematician stuff, then I'm going to call foul on it because we need to keep this in reality space.

MR. KURITZKY: Okay, very good.

MEMBER BIER: Well, another way of asking that question is not just is, you know, is 10 to the minus 13 actually zero?

But also just, is that number meaningful, you know, do we know that it's 10 to the minus 13 as opposed to 10 to the minus of 9 or 10 to minus 17?

(Off-microphone comments.)

MEMBER BIER: You know, yes or a significant figures there.

MEMBER MARCH-LEUBA: This is what the question is a follow up, something I've been dying to put on the record. The age of the earth is considered to be 5 billion years.

In your numbers, it's 10 to the minus 10. Over 10 to the minus 10 per year, we have meteorites that hit the earth so hard that ejected the moon, that the bottom of the Indian Ocean is now in the top of the Himalayans.

So, 10 to the minus 10 is zero. Okay? Because in this calculation, you didn't have earthquakes that put the bottom of the Indian Ocean in the Himalayans.

So, and we did have a -- I was -- I wouldn't call it a retreat, but an international meeting of ACRS like members.

And I appreciated much one of the Japanese members, which I don't remember his name, says, we need to start concentrating on these terminal events because that's what really is going to be on these new reactors. And according to your calculations, these are for all reactors 10 to the minus 13.

So, in an attempt to understand rates,

that's the age of the earth, I mean, anything lower than that, obviously, your calculation is incorrect.

So, roughly, at 10 to the minus 7, in my mind, is 10 to the minus 7, is where you need to start considering external events and your calculation is incomplete. And certainly, I was going to say incorrect, but certainly incomplete.

CHAIR REMPE: So, to try and get us back to Volumes 3 and 4, which is the topic of the meeting and we do a letter, and the topic of the letter, I'd like to talk a little bit more about benefits, not only to the NRC, but also to industry who has helped participate in this.

And I was wondering, your qualitative screenings approaches and methods, that's something that could be cited as a benefit even in these volumes before you get to the summary that you've made some progress in thinking about approaches that people could adapt? Is that a true statement?

MR. KURITZKY: Yes, I think so. We did a fairly extensive screening of the other hazards.

Anders Gilbertson who is now with NRR, but was a researcher on this, and performed a very detailed evaluation of hazards and did some very good screenings, both qualitatively and some quantitatively, depending on the particular hazard using the criteria from the PRA -- the ANS, ASME Level 1 LERF PRA standard.

So, there's a lot of good insight there as to why we do or don't consider certain events and someone else can take a look at that, another stakeholder can take a look at that and say, hey, all right, well, this is the approach they used.

Is that -- well, if I follow that approach, is that something that will get me a similar result or not? You know, it depends on the specifics of the site.

CHAIR REMPE: Okay.

MR. KURITZKY: But and again, I do want to caution that because we do it one way doesn't necessarily mean that it's an NRC approved approach.

Someone mentioned that before about whether we had approaches that demonstrates other approaches that other people use.

In most cases, they probably can. But again, the NRC has actual reg guides and other guidance that tells licensees what are approved approaches. And we are not undermining or countermanding any of that.

If the NRC sees the results of stuff we've done or the approaches we've used and they believe that they want to adjust the guidance, if, for some reason, we did something different than what the current guidance says, then that will be a separate effort.

So, we are not -- no one should take what we've done today, this is the NRC approved way to do that. This is what we felt was the best way to do it within our time and resources and level of information we had available.

But it doesn't -- isn't, you know, a tacit approval that this is an appropriate approach. So, in most cases, it probably is, should be an appropriate approach.

But in any case, yes, going back to your comment, Dr. Rempe, yes, I think the screening analysis we take is very useful for them to have documented. And again, that's Volume 4C.

MEMBER DIMITRIJEVIC: Alan?

MR. KURITZKY: Yes, Dr. Dimitrijevic?

MEMBER DIMITRIJEVIC: So, here, first, I just want to -- the level of -- come back to the screening. I just want to say something from the previous discussion and Jose's questions.

How I see this question is not is the

Level 3 worth it and whoever, you know, that investments, I want to stay totally out of the investment part.

But my question for the industry would be, is the Level 3 ready to be used? Because this is why I think it's a little above your pay grade and pay grade of every PRA analyst, can we, with a straight face, present those numbers and say that we believe we're done?

You know, even with -- because that's definitely zero. So, if we present a number which says that given the a lot of Volume 6, in the original early fatality risk is in the, you know, you need a thousand times years than the age of the universe, can we say this with straight face? And I would not be able to do that.

So, my thing is, is not how much it costs, are the technical abilities of Level 3 ready to be used? So, that's what -- how I would ask that question.

The second thing is, that when it comes to the screening of hazards, I know the study you said that you actually did believe there was a couple hazards, I think maybe three, that you didn't really think there was enough knowledge.

Are we able to screen those hazards that you sort of left for the future? But they not considered screened out?

Those hazards are, I think there was like heavy load drop and intense precipitation and the space events. So, does that mean sort of we screen all the hazards except the three which require future work?

MR. KURITZKY: So, let me see if I got your question correct, Dr. Dimitrijevic.

Are you saying, did we screen everything except those three? Was that the --

MEMBER DIMITRIJEVIC: Yes, is that how your position, is everything screened except those three which require further work?

MR. KURITZKY: Yes, my understanding is, based on the criteria in the standard, except for the several that we have quantified, everything else, the plant has screened out except for the ones that we mentioned.

Locally, intense precipitation is one that, because of the particular, let's see, what is it, topographical conditions of a referenced plant, flooding from versus the ultimate cooling source would be a threat to the plant.

But potentially very high rainfall, you know, locally heavy precipitation might be. But because at the time, there was active research into upgrading that methodology and the data, so we did not pursue it.

So, I don't know what the impact on the referenced plant would be. Space weather is clearly something out of our realm of capability to analyze at this junction in time, though it's certainly something that I can envision being a concern.

I mean, I can envision it being a concern for a lot more than just a nuclear power plant.

I don't remember what the third one was, but I think, beyond those, we -- I think we've handled or addressed everything that was in the standard.

CHAIR REMPE: I think it was heavy load drop is what --

MR. KURITZKY: Oh heavy load drop, yes, yes, thank you.

CHAIR REMPE: And I mean, that's happened.

MR. KURITZKY: Yes, heavy load --

CHAIR REMPE: -- and you couldn't analyze that?

MR. KURITZKY: Yes, I don't remember what the specific reason -- I don't recall what the -- what it says in the report about heavy load drop --

MEMBER DIMITRIJEVIC: So, my point is, we cannot say they're all screened. Three of them are certainly, you know, hanging in there. We need more knowledge about them. That's what my point is.

MR. KURITZKY: Yes, yes, definitely. Yes, I agree wholeheartedly, yes.

CHAIR REMPE: Could you add some of your thoughts about Vesna's question about could you -- is it ready for prime time? Level 3, is it ready to be presented with a straight face, is I believe what she said?

MR. KURITZKY: So, again, this is my personal opinion, because -- and I'm not authorized by NRC to make statements broad based like that.

But again, my personal opinion, we're dealing with something that has a lot of uncertainty.

If you have Level 1 -- we've been regulating CDF and LERF for a lot of years. Right? And there's a lot of uncertainty in the calculation or estimation of CDF. Okay?

But yet, and so, as I mentioned before, we don't have a risk -- we don't risk-based regulation, we do risk-informed because we acknowledge there's uncertainty and we have to balance that uncertainty or compensate for it with other things like defense in depth and safety margin, right, deterministic approaches.

But we can use it to help inform our decisions which is really what it's range is.

Now, as you go from Level 1 to Level 2, you go from any A to B, you're adding more. And the more you add, the more uncertainty you have. Right?

And particularly because, as we're going from Level 1 to Level 2 to Level 3, we're actually getting into, at least in my opinion, more uncertain areas.

So, you're seeing an expansion of that uncertainty.

The numbers are naturally getting all right, because you're adding more things to go wrong. So, even though the tone of uncertainty is getting broader, the numbers are getting lower. So, maybe you're still and can demonstrate below an acceptable level.

But again, that's a case by case situation.

As we're going to talk about in the later slides, the parameter of uncertainty, which I only -- I don't give a lot of credence to it, personally, but you have -- we have failure type distributions and even at Level 1, 2, and 3.

In Level 3, we only do parameters for a very small piece, but still, they're failing type.

But what I believe is the bigger uncertainty that really throws the question, is this ready for prime time? Is the modeling ready?

Because there's many things that we either don't include in the models, that we don't have sufficient information to do a good job of modeling on the simplifications, or we have to make, you know, key assumptions.

And some of those, if we do sensitivity analyses on them, we see, you know, just engineering judgment or sensitivity -- quantified sensitivity analysis, you see how these things can make a big difference.

And that doesn't mean whether or not something goes from 16 minus 13 to 10 to 20 minus 12 because of ground runs. It's 16 minus 13, maybe 260 minus 7.

There's going to be one example that I'm going to get to later on in this presentation that has some very substantial impact on that. And those are early fatality risk value.

So, the more uncertainty you have, obviously, the less useful the results. Right? Or you have to use them with more care. You have to use them with more care.

I still think that it can be useful, but you have to take it into context. I mean, you can't make a decision based solely on it. You have to use that as another piece of information to help make an argument that's going to involve multiple pieces of information.

MEMBER BIER: So, that brings up another good point about the modeling uncertainty.

I mean, currently, when we do uncertainty analysis, we do only a parametric uncertainty. And then, we might say, okay, there's a factor of three uncertainty around that 6 minus 13 or whatever.

But it may be, in fact, much greater once we have model uncertainty in there and we don't really have very good ways of quantifying that.

So, in cases where the modeling uncertainty really swamps the parameter uncertainty, I think, you know, again, doesn't mean it might not be worth doing, but it seems like we need, you know, a new level of caveat on that kind of situation rather than just, yes, this is accurate to, you know, a factor of three or a factor of ten.

MR. KURITZKY: And Dr. Bier, thank you for that comment because that's really something I had mentioned before. I'm not a huge of parameters for that very reason.

MEMBER BIER: Yes.

MR. KURITZKY: Because I think the modeling uncertainties greatly outweigh the parameters.

But I do want to take exception, we do have ways of treating model uncertainty --

MEMBER BIER: Okay.

MR. KURITZKY: -- through sensitivity analysis.

It's not complete and, as I was going to mention, I'll mention it now, when we do our sensitivity analysis, we're doing them in a, not a great term, but it's called stove pipe situation.

We're looking at them individually.

MEMBER BIER: Yes.

MR. KURITZKY: So, we're not looking at, you know, here's a different model for this aspect of the PRA as much as we think that might be with sensitivity analysis, here's some other ones.

I don't know if we did this one this way and that one that way, and this one this way. We don't -- we can't take, you know, if ones -- the combinations are endless.

So, even one at a time, we only have a certain number we can look at.

But yes, I believe all those modelings are what's really the big thing that you have to consider.

MEMBER REMPE: Okay, colleagues, we have -- there's -- Walt has a question and we'll let him go first.

And Dennis and Susan both have their hands up.

And I didn't see how long they've been up, but then, we need to move on because we've spent a long time on the first six slides.

Go ahead, Walt.

VICE CHAIR KIRCHNER: Okay, quickly, Alan, while it's up, could you, later in your presentation, comment on the FLEX versus the 2012 results and whatever insights you would extract from those deltas there?

And I'm looking at the, you know, the last two columns and the delta between 2012 and FLEX.

MR. KURITZKY: Certainly.

So --

VICE CHAIR KIRCHNER: Any insights that you gained from that.

You can come back to it, if it's part of your talk.

MR. KURITZKY: Okay.

So, thank you, Dr. Kirchner.

That actually is part of that discussion that we're not going to have -- we were not going to have because that was something that we discussed at the subcommittee meeting and I was -- got guidance to focus on other things.

But going back to that slide, real quickly, because I can do that for you just real quickly as you look at the numbers.

So, if you look at the core damage frequency and the large release frequency and individual latent cancer fatality risk, all those go down around 40 percent from the 2012 case to the FLEX case because they're all based on the same thing, and that's they're driven by station blackout related sequences.

Remember, FLEX as it's implemented, is to focus on extended loss of AC power sequences.

And so, that's the kind of stuff that it's really good at.

The referenced plant, its risk profile, its CDF profile is a highly -- it's a large contribution from station blackout sequences.

So, FLEX has a fairly significant drop.

If you have a plant that its risk profile is core damage profile, it's not heavily contributed to by station blackout sequences, you will not see nearly the impact in FLEX that you have here.

So, and the reason the other two large early release frequency, individual early fatality risk don't see as much of an impact is because there were a lot of climbs, but other sequences like interfaces and LOCAs or things that FLEX would not be that effective at.

VICE CHAIR KIRCHNER: Yes, I just wanted that on the record.

Thank you.

MR. KURITZKY: Okay.

CHAIR REMPE: Dennis?

MR. BLEY: Yes, thank you.

We had a lot of discussion about the low numbers, 10 to the minus 13 kind of things.

But I think it's important to get some language right here.

The first three are frequencies of events in the plant, the event core damage, the event early -- large early release, and large release.

The next two are labeled risk. And Alan, I don't have the report open in front of me, so I'm not sure exactly what these are.

They could be the frequency of one or more deaths.

They could be the mean value of one or more deaths.

But they're not frequencies like the first three.

And we had a nice discussion in the subcommittee about why numbers get very small when you go from the event, say, large early release frequency, that can lead to possibly early fatalities.

That then is getting distributed. We're not talking about events after this, we're talking about cases where are there people in the path? Are there people in the path close enough to be exposed?

What are the weather scenarios? How's the wind blowing?

So, it's distributing the results of the release calculation to places where there are people or are not people over a time period during which things change from it being possible to have early fatalities to not being possible during that time frame.

So, we just throw these exponential numbers up without -- we've been doing it so long, we forget to tell people what they are.

And I don't have the book out in front of me. So, on the two -- last two, I'm not exactly sure what these numbers are.

And if you can tell me real fast, Alan, that'd be nice. If you can't, we ought to go back and take a look because people present them in different ways and they can be anything from expected values to frequencies of particular accumulations of events.

That's all.

MR. KURITZKY: Okay, thank you.

I'll try -- okay, just thank you, Dr. Bley.

Yes, I think the next slide actually goes directly to that item.

CHAIR REMPE: Okay.

Then, let's let Susan have her turn.

Susan?

MS. COOPER: Thanks, Joy.

Yes, I just wanted to throw out a little bit more on the topic that we've been discussing and that Dennis just contributed to significantly.

I just wanted to take a real quick look at the summary volume for NUREG-1150.

And the example results in that -- in the introductory section showed something on the order of 1E to the minus 6 for results for early fatality risk and latent cancer risk.

So, if nothing else, when we're doing our comparisons with that earlier NRC study, we can see that there is a difference in our results, probably a combination of not only differences in how well we can calculate things, the models and tools we have, but perhaps also operational differences.

But in any case, that is, you know, the numbers have some meaning, I think, in that case also.

CHAIR REMPE: Okay.

I think we're ready to go to slide 7, Mr. Kuritzky.

MR. KURITZKY: Hey, here we go, made it.

Time for a break? No, I'm sorry.

So, just a few insights. I wanted to discuss, since we did most of the results discussions back in the subcommittee, I wanted to focus this more on the preliminary insights.

Just some, again, this is something that will have to be done when we delve into Volume 1 later and look across the whole study and including the study -- the parts of the study that deal with other things like low power shutdown, spent fuel pool, et cetera, things that haven't already been run to ground in previous studies throughout the technical community.

So, one of the things I do want to mention from the work so far on the reactor at power PRAs is this topic we've just been discussing.

So, what we see from that previous slide and what we've talked about in October 19th is that, for this plant, in this location, there's a substantial margin to the two quantitative health objectives associated with the condition or safety goal.

That's the individual early fatality risk, the individual latent cancer fatality risk.

However, those margins are much less when you look at the certainty in these metrics of CDF and LOCA.

Now, why is the early fatality risk so low, and as Susan had mentioned, that's something that wasn't nearly as low in NUREG-1150. That's something I think that Keith is looking into.

And I don't want to bring Keith on to sidetrack us right now, but that's something we are going to try and address in the final summary NUREG.

But the reason we're getting numbers that are so low is exactly as Dennis was -- sorry, Dr. Bley was just mentioning.

And that is that the type of events that we give with these large fast releases that are going to lead to potential for early fatalities are very low, at least in the study, probably in many studies.

And that's because they're really things like interfacing system LOCAs or they're other contained bypass like steam generator tube ruptures that are going to get the radiological release out in a hurry and not be mitigated.

And so, that is something or those are things that have very low frequencies.

So, right off the bat, you're starting with a very low frequency number.

Then, and that's what Dr. Bley was mentioning. Frequencies of events will also be low.

But then, when we get to the quantification of individual early fatality risk, there's not a number of other factors that we're going to have to consider.

And for instance, they're listed here in some of the bullets right here, they're the main reasons.

One is, you have to have weather conditions that are conducive to having a large exposure event.

And that means, relatively stable, low wind speed conditions. So, radiological cloud meanders over people.

Second, or second or third, third bullet, you have a very sparse enclosed population at the reference site.

And this is, of course, going to differ for other sites.

But nonetheless, that release has to be targeted at where the people are.

So, if you have -- I think we have 360 receptors, okay, so, you know, you have to -- there's only, I think, I can't remember, but in any case, the wind has to be blowing at that sector, and I think only or two have people in it. So, it would have to blowing in that direction.

Right there, you're knocking another quarter magnitude or two on top of the frequency results.

On top of that, the people are going to be evacuated. There is almost all these situations, there is sufficient time to have effective evacuation.

So, really, what you have to do is have some people that are not evacuating or get caught in the -- there's very low likelihood of the delayed or slow evacuation that will lead to a high likelihood of that.

So, when you multiply the probability of not having successful evacuation or take only the fraction of the cohorts that are not successfully evacuating, they're knocking down another order of magnitude.

So, what happens is, that individual early fatality risk number that we see, that 10 to minus 13 number, is an amalgam. It's, you know, the multiplication of multiple factors that keep knocking it down.

You have a very low frequency and you have a lot of conditional probabilities for various occurrences or just really physical conditions that now start to knock it down by orders of magnitude.

In the final summary NUREG, we're hoping to give some kind of a little, you know, it's hard to draw exact numbers for every different case, every different scenario, but to give some ballpark idea.

Because this one, the 10 to the minus 2, the 10 to the minus, et cetera, to show how we go from the 10 to the minus, let's say, 6 down to a 10 to the minus 12 or 10 to the minus 13 number.

But that's the reason why we come up with such a low number. And it's really what Dr. Bley was saying.

You have a low frequency event, but then, you have all these other factors that drive that number further down.

MEMBER ROBERTS: Okay, so, that's the individuals early fatality risk.

Now, the latent cancer fatality risk on the -- just to clarify a little bit more, you said that first number is the LERF, right? The very low frequency of bypass events?

So, that's --

MR. KURITZKY: Yes.

MEMBER ROBERTS: So, that's just kind of a starting point?

MR. KURITZKY: Yes, essentially, like --

MEMBER ROBERTS: So, there's still another six plus orders of magnitude for those next three bullets?

MR. KURITZKY: Yes.

MEMBER ROBERTS: You're saying you're going to put together a chart in the final report. I was just trying to get some perspective, are one or more of those more dominant than the others?

Because it's kind of hard to see six or seven orders of magnitude between those three bullets.

MR. KURITZKY: Again, we're going to try and do that.

And I was just mentioning, it's not that easy because they're not just like solid, you know, single numbers that we can just say, this was 10 to the minus -- in all cases, this is 10 to the minus 2.

It's going to vary case by case.

But we want to get like a typical value like the likelihood of adverse meteorological conditions are generally like around this order of magnitude.

And the very sparse, close population has this order of magnitude impact.

And the likelihood of delayed evacuation at this order of magnitude and that.

To get kind of an idea.

But yes, that's the idea, that they will --

MEMBER DIMITRIJEVIC: Alan? Alan?

MR. KURITZKY: Yes?

MEMBER DIMITRIJEVIC: Let me just ask you, I mean, you know, the definition of the -- we also struggle with the PRA or definition of large release and large early release.

Does a large early release implies large release before, is my question, is initiated?

MR. KURITZKY: Yes, it does imply large release before a successful evacuation.

Let's say, there was the potential -- in our definition for this site, so there is the expectation of a potential for early fatalities.

And that's why that number -- that first bullet has a low number because, just having -- the types of sequences that will have a low likelihood of occurring, there's a very low frequency of things that could potentially not have an evacuation.

But even those, it's the potential, it's the expectations or potential for early fatalities.

So, you still might be able to evacuate, but you still may get enough exposure that you have early fatalities.

So, again, LERF is a surrogate risk metric that has served us well for a long time and will probably continue to serve us well, I'm sure, for the future.

But it's not the same thing as what you go to in individual early fatality risk.

So, like I said, we're going to try and see if we can make some kind of mathematical connection to show how you get from one to the other. But it's really not -- we're not comparing exactly the same thing.

So, unfortunately, I don't have a better answer for you. But LERF is not exactly the same -- in the same alignment when you just go -- when you calculate individual early fatality risk.

LERF isn't like, here's the first step and now, you can add these other steps. Okay?

It's going to be, these types of events are listed in that first bullet, and then, these other types of things.

Whether those are specific to LERF, many of them will be LERF, but LERF may include other things that are not part of that.

I don't know if the reverse is true, probably -- I don't know. We do have things that we can sort of do LERF that might not have --

Yes, we do have things that we consider to be LERF that were not -- that we ultimately show were not contributors to individual early fatality risk.

Because the frequency was so low or the magnitude of the release just wasn't high enough to have a reasonable expectation of early fatalities.

So, again, they're not the same exact thing. So, it's a little difficult to just make that into a mathematical expression.

But at least we can have some idea of what these other factors are so that, in just people's minds, we can say, hey, whether it's exactly LERF or not, the frequency of such events is either 10 to the minus 6 range, how we get into the 10 to the minus 13? Well, here's some of the factors of getting us to a much lower number.

That's really what we're trying to get to.

Okay, so, moving on to the second bullet, so latent cancer fatality risk, and as we've talked on the previous slide, it also had a fairly decent margin to the QHL, but not nearly as much as large early release rates.

But the reason it does have a significant margin is, again, for some of the very same factors that we saw -- that I just discussed for early fatality risk.

Because those same factors are why you have very low doses in the early phase.

And effective protective measures also mean that we have fairly low doses at the latent or the early -- excuse me, in the late phase.

So, combined together, there's a fairly low likelihood of having latent cancer fatalities also, just not nearly as low as the early fatality risk.

Next slide, please?

Okay, so, just to dig -- we talked a little bit about this, but to dig a little deeper, peel another layer of the onion off on the early fatality risk.

First of all, let me just mention that, in our Level 3 PRA, again, I mean the consequence analysis, risk analysis reports, part of the Level 3 individual piece, we report risk -- a number of risk factors. I think there's over a dozen risk factors that we reported results for.

And they're basically broken into two different categories, those that are related to early health effects and those that are not related to early health effects.

And the reason we break them into those

two types or it's because contributors are pretty similar for those two categories. Like almost everything is in each of those categories is relatively similar.

For the early health effects, the primary drivers, I think we kind of mentioned this a few minutes ago, are interfacing system LOCAs if they bypass containment and we have a very large release.

And that's primarily -- the main contributor primarily to internal events because that's where we have the model.

There's a little -- there's a modest contribution to seismic because the largest seismic or our model seismic is a very large seismic event that has -- it doesn't bring the ocean on top of Kathmandu or whatever it was, but it does lead to a very destructive earthquake.

And Because there was wide scale damage at the plant, we assigned that to the release category that has the highest source term magnitude, which is the interfacing system LOCA.

So, that's why you get some contribution of seismic from the interfacing system LOCAs.

The other two that really contribute to early health effects are steam generator tube ruptures, both before core damage and after core damage.

The pre-core damage ones, pressure induced steam generator tube ruptures primarily come following an ATWS event, anticipated transient without SCRAM where there is at least one secondary side valve open, either the operators have intentionally opened or it's stuck open, but that's your relief -- release path.

And those particularly are -- contribute to internal fires and seismic events. Those are the ones that have a higher ATWS contribution. So, they have a bigger contribution from these pressure induced steam generator tube ruptures.

The other big contributor to the early health effects is post-core damage, thermally induced steam generator tube ruptures. And that's after core damage when you have high gases in the steam generator tube, then you end up having a steam generator tube rupture there and then, again, you have potentially bypassed release.

And those affect actually of the hazards having a contribution from those, though particularly high wind and internal fires are a particularly large contribution for releasing thermal inducted steam generator tube ruptures.

Next slide, please?

Oh, a question?

MEMBER BIER: If I can just make a brief comment, kind of echoing some of what Jose has been talking about?

If I was asked before this presentation, what do I think the biggest contribution to early fatality risk is? I would have said interfacing systems LOCA.

And so, is there a lot of nuance that we gain from the analysis about some of these other contributors or, you know, could we have had this conclusion without doing the Level 3?

MR. KURITZKY: So, that's a good question, the -- a fair question.

And yes, would also assume ISLOCA. I mean, even though we must -- I'm a Level 1 PRA guy, so my level is Level 1 PRA.

I thought Level 2 and Level 3 was just hoodoo voodoo stuff, I don't know.

Even success rate, I always thought -- this is one of the eye openers -- I always thought the success criteria you get in a Level 1 PRA or the thermal hydraulics guys were on the MELCOR or whatever at, and here's, you know, two out of three pumps, whatever, here's this affect.

That was -- there was -- that's what the answer is. Now, we'll go play our numbers game on the rest of it, but that's the answer.

Well, I started -- I had to review that section of the report when I was, years ago starting this project. And I'm like, whoa, whoa, you know, we just took a few cases here, a few cases there.

You know, at this end of the LOCA section, you know, that may not hold a totally different thing at that end.

And you know, so, there was uncertainty, right, throughout all of it. It was a big eye opener is sort of the rest of it.

But nonetheless, ISLOCA was something we all, of course, knew by definition, it's the interfacing LOCA that goes -- it's potentially a thing that goes up containment -- it bypasses containment.

So, we know that's important.

But we learned certain things, first is, ISLOCA is, as I was mention later, is something that the frequency of ISLOCA, we had taken some data that Idaho National Lab had in their operational database to come up with quantification -- the drivers of ISLOCAs are primarily large leakage through closed, shut valves and/or motor operated valves in the RHR system, primarily.

And we portray some very minor amounts of data to come up with frequencies of what's the likelihood of that happening? And the numbers were not -- didn't seem realistic.

So, we actually decided to go with an expert solicitation to come up with a better idea of the frequency of those things happening as well as the distributions to use for the analysis.

And so, we learned quite a bit about the mechanisms of ISLOCAs. So, we always learn other things about -- we also learn, yes, we knew ISLOCAs that, in Level 1 space, we don't know the temperature of new steam rupture options of those in the core damage if steam ruptures are a major contributor. We don't look at that on Level 1 space.

But there are other things that do show up to be important.

ISLOCAs, specifically for internal events, Because that's where we found we didn't have any cases in high winds or fires where we thought ISLOCAs were going to occur.

So, there are other things that contribute to risk.

So, when we look now at non-external events, but all hazards, there were different things that now show up to be important contributors.

So, yes, we can surmise many of these things, A, priority, this either confirms it or gives us more information.

In some cases, it might countermand an understanding we had before that's less likely to occur, especially after we've had this for many years.

But yes, so there's incremental increase in information and knowledge. Whether the banker wants to pay for this or feels it's worth paying for it, that is an open question.

MEMBER BIER: But there is an increase?

MR. KURITZKY: Right.

Okay, I think we've finished this.

Next slide, please?

And Dr. Rempe, I'll let you let me know when we're running out of time.

CHAIR REMPE: Okay.

MR. KURITZKY: What's that?

Okay, okay, so, for those risk factors other than the early health factors, which are things like latent health effects, affected population, land contamination, et cetera, so those, again, all them, generally have the same set of drivers also.

The two biggest things that drive them are late containment failures due to over pressure that occur tens of hours after vessel breech and the releases are not scrubbed by either an overlying pool of water or by containment sprays.

So, you get a fairly large release.

Also, there are events that occur several hours after vessel breech and due to combustion events, whether through deflagration or detonations, and that caused the rupture of the containment.

And again, those also are unscrubbed. No overlying pool of water, no containment spray.

So, those two really drive the other than early health effects measures.

We have another one more specifically for seismic events is contained isolation failure.

And that's Because, some of this -- particularly the larger sized events, they can structurally damage the containment isolation system. So, you can get, particularly there, you can get a release that is not mitigated.

And the last one, again, the thermally induced, that's the post-core damage steam generator two ruptures.

This one contributes to across the board for all these hazards but, primarily, from land contamination.

Actually, for the other risk measures, it's just a few percent contributor, but it's over 10 percent for land contaminations.

Okay, next slide, please?

And just a few more insights before we move on to Level 2 HRA.

So, this is something we just discussed quite a bit at the subcommittee meeting.

One of the things that we did for this study is, we wanted to have a good understanding of severe accident progression in the longer term as well as impact on radiological release.

So, we carried out the severe accident progression analysis until a stable condition was reached with a seven-day backstop.

And oftentimes, that seven-day backstop is what ended the analysis.

So, in doing so, we identified one of the major contributors to these non-early health effects risk metrics was the -- what I just talked about, which was containment over pressure, tens of hours after vessel breech, which eventually grows to release large enough that it becomes a major contributor, what we call large, and then, becomes a major contributor to increased risk fatality as well as the other risk metrics.

And because of that analysis, we know two things that are very important to take away from that.

That if you can do something to prevent that over pressure, then two or three days after the event initiation, you can prevent that large release.

So, if you could do something like containment venting or restore containment heat removal, you can prevent that release -- that large release from every occurring.

On the flip side, if someone were to perform a Level 2 PRA and submit its results, and they only modeled severe accident progression for 48 or 72 hours after the event, essentially, then there's a good chance they're going to really under rate the expected risk.

The other one that has a large contribution to these latent -- these non-early health effects is the one I mentioned in the last slide, too, which is the several hours after vessel breech, you get a -- either a deflagration or a detonation in the combustive gas.

And that one is, particularly the way we treat combustion in our study, we can treat combustion as a casket process, probabilistic process.

Many other Level 2 PRAs treat combustion deterministically. In other words, they set a level that, once the concentration of a combustible gas in containment gets to this level, you are definitely going to ignite it.

You have you deflagration, whatever, that knocks the level down. And then, you can start building up again.

Well, if you do that, you never really get the high levels of concentration that can lead to such an energetic deflagration or detonation, you can really challenge containment.

If we treat it statistically, there's a probability that you might not detonate at those lower levels. That even if that probably is not that high, it's still there and so, there's the potential that you will build up to a much higher level of concentration of combustible gas so that if it does ignite, you can have a very energetic event that's much more likely to fail containment.

So, that's, again, a modeling of uncertainty issue or, you know, the choice that people make compared to studies that have also modeled combustible gases but with surpass the process are results are fairly similar in terms of the results.

Okay, next slide, please?

Okay, I get my dry throat to get a break.

Dr. Cooper will now carry us through the post-core damage human reliability analysis.

Take it away, Susan.

MR. BLEY: Alan, before you go, this is Dennis again.

I just wanted to say something in support of your statistic approach.

And you probably are aware of this, but we were out talking with the NST people some years ago and they tried to recreate fires both, I think, both Class A and Class B fires by setting things up in their hoods exactly the same, starting the fire in exactly the same way.

And every time they did it, they got a very different progression of the fire.

So, I think you're on the right approach.

MR. KURITZKY: Thank you, Dr. Bley.

Yes, I think that's a good analysis, thank you.

MS. COOPER: All right, good morning,

everyone. This is Susan Cooper from the Office of Research. And I'm going to talk a little bit about the Level 2 HRA analysis that was performed to support the Level 3 project.

The actual development of this approach and the application for quantification occurred back in 2015, 2016. At that time, I was not aware of anyone else that had developed an HRA approach to address Level 2.

Also, at that time, severe accident management guidelines, SAMGs, were relatively new on the scene so far as a tool in the toolbox for utilities to address accidents that progressed to Level 2.

So, this posed a new problem for HRA. And the SAMGs were definitely the focus of that, but there were some things that went along with that that were important for us to try to consider and get a handle on how to model.

The SAMGs themselves were different than EOPs. They are a guidance, not step by step oriented procedures. And there are options not necessarily just one thing to do. And they're also are hierarchies, depending on the plant conditions.

Also, less training and experience and

also, the decision maker changes, the power shifted from the control room to the technical support center.

And the emergency director there in the technical support center was the final decision maker supported by what are called SAMG evaluators.

So, there's a different team associated with implementing these procedures.

So, the approach that we developed is principally based on, you know, our understanding of the SAMGs and other procedures at the reference site.

But then, most importantly, based on information collected during a plant site visit, especially one done in summer of 2013 where I interviewed a number of operators and resident inspectors, trainers, managers who had the responsibility of being emergency director and the TSC.

And they also, that the reference site had the previous year conducted a mini-E drill that went into using SAMGs.

And there were specific things that were done in the TSC in using emergency damage mitigation guidelines, EDMGs, even though there's no explicit procedural link between those procedures and the SAMGs.

Also, based on a recommendation from Dennis, I looked very closely at Gary Kline's naturalistic decision making approach, specifically, two models that he has.

One for team decision making and another called recognition prime decision making.

So, both of those were important for us to try to understand what was really a team in the context of post-core damage and what is an expert and what is the process for decision making?

Next slide, please?

CHAIR REMPE: Susan, this is Joy.

MS. COOPER: Yes?

CHAIR REMPE: And maybe Dennis may have to help me remember, but after Fukishima, we had presentations from the BW owners' group as well as the PWR owners' group, as I recall.

And about the SAMGs and how they were being changed to address Fukishima.

And your comment about the decision maker going to the TSC is not consistent, and maybe, again, I did -- my takeaway from those discussions were that, it depended on the plant.

But the -- my takeaway was, generally speaking, that the TSC folks just recommend to the operators they are the ones who are still the final decision makers because they may know, well, that particular --

Because their basing their decisions on what instrumentation is still working and trying to say, okay, two out of three say this. And one may say something different.

But the operators may still know, well, one of these often doesn't behave as expected.

And your comment about the TSC being the key decision -- or the power goes into the TSC, is that just something that this reference plant or is --

This one kind of puzzles me that, you know, when you make that statement --

MS. COOPER: So, yes.

MR. BLEY: So, okay --

MS. COOPER: Dennis, you want to go ahead or I mean, I can go ahead.

MR. BLEY: Yes, I was just going to try to clarify what happened back then.

Early on in our discussions with various people associated with the industry, it was always said, the licensed operators in the plant were the decision makers throughout this.

But as the SAMG work went on and the

industry as a whole worked on this together, that kind of shifted in a --

You'll even find, my memory is, in the procedures where it tells you to consider these, that operational control does shift to the TSC.

Now, maybe not all plants have implemented it the same way. The people who are hands on and actually do things still have a voice and are the only ones who are allowed to operate the plant.

And maybe some of our folks that came out of industry can say more about this.

We also had an NEI arranged session, and this was on the boiling water reactors, not the -- we never got around to having it with the pressurized water reactors --

But they brought in people from one of the plants and big charts of the SAMGs and how they were going to use them and the other related procedures, and walked through a number of possible events and how decisions would be made and how things would progress.

And I think the Committee still has that information somewhere in our archives. I could probably help with that if people need help.

Anyway, that's a quick summary.

MS. COOPER: Yes.

MR. BLEY: And Susan, what you found might be different.

MS. COOPER: Well, no, I think that's probably consistent.

Although, remember now, we were dealing with procedures from 2012.

But the bottom line is that the Westinghouse SAMGs have a very specific indefinite transition from the control room to the TSCs so far as decision making shift and when the TSC takes over.

And that's when the thermal couples reach, I want to say, 1,800, I can't remember, but, you know, basically, the definition of core damage.

And obviously, the concern then is, who are those decision makers?

Now, I can't speak for industry as a whole, but what I found, at the reference site was, it didn't leave operations Because the three, no, four decision maker managers who would have been -- had the role of potential emergency director and the TSC were all either current or former SROs licensed at that plant.

On top of that, the -- so, the SAMG evaluator who is the one in the Westinghouse SAMG structure, actually comes up with the operational approach is, in fact, the operations representative in the TSC, a slot already assigned, and he is in charge with support from engineering.

For the mini-e-drill that was conducted in 2012, it happened to be an SRO, but it will always be someone that was a licensed operator.

I even talked to that SRO while he was on shift in the Unit 1 control room.

So, for this referenced plant, that was their model was that, you know, operations operators were still going to be very much in control.

Now, recognize with SAMGs and even, you know, linking them to EDMGs, we're mostly talking about actions and equipment outside the control room and, you know, portable equipment and so forth.

So, anyway, the bottom line is that, while it shifted for this plant, it didn't really get out of control of the typical operating operators' group or the operational group.

So, that was an important insight that I got from that plant site visit. And very much changed my view of what the team was for implementing SAMGs.

It was certainly still a larger team, but it was still within the group of people that ordinarily are in charge of operations.

CHAIR REMPE: Okay, thank you.

MS. COOPER: Steve's got his hand up.

MR. SCHULTZ: Susan, this is Steve Schultz.

MS. COOPER: Yes?

MR. SCHULTZ: So, a quick question here.

MS. COOPER: Yes?

MR. SCHULTZ: You've talked about what was done in the overall work that you performed in 2012.

With the work that came in with the FLEX strategies and the equipment availability and so forth, did you update the overall evaluation of human reliability in this respect once that was implemented, that would have been fully implemented a couple years after the time frame that you're talking about here?

MS. COOPER: The short answer is, no.

And Alan can probably speak better to how HRA was addressed for the FLEX sensitivity cases.

Remember, this is the FLEX work is not a fully performed PRA and HRA effort.

So, the answer is no.

I will say that, you know, as also the current lead for the integrated site risk task that we will at least qualitatively take some of that into consideration when we consider a site wide event that involves the two reactors, spent fuel pools, and dry cask storage all at once.

But so far as the Level 2 HRA work that was performed, no, we did not update the Level 2 to take into account FLEX.

MR. SCHULTZ: That -- I'll listen to Alan on that one, too.

But the overall approach sounds good to take that into account as you look at the impact of that --

MS. COOPER: Yes.

MR. SCHULTZ: -- in your review.

Thank you.

MS. COOPER: Mm-hmm.

All right --

MR. KURITZKY: Susan, sorry, Susan, just Because Dr. Shultz just had -- he mentioned my name, so I have to pipe in because I love the sound of my voice.

So, Dr. Schultz, as Susan said, we did not update the Level 2 HRA once the newer SAMGs came in, I think was the beginning of your question.

And so, with -- and with the FLEX, as Susan mentioned also, we did a very course evaluation. So, we don't -- we didn't do a detailed HRA.

And again, I want to re-emphasize that that doesn't mean other people incorporated FLEX into some risk-informed licensing amendment shouldn't be doing a detailed HRA. They very well might need to do that.

But for purposes of our study, we didn't do it.

So, the fact that the -- that is was new SAMGs really wouldn't impact our FLEX analysis.

The one place where we were considering using the new SAMGs was for low power and shutdown, I believe, because I think shutdown was not part of the original SAMGs.

But then, it did become part of the updated ones, but I don't think, I'm looking at Jeff Wood, I don't think we ended up doing anything with it -- with the updated SAMGs, even for low power shutdown.

Well, nod your head, I can say it, otherwise, you have to come to the mic.

That's correct. Jeff says that's correct.

MR. SCHULTZ: That's great, I appreciate that.

It sounds, from Susan's description and from what you've provided, it sounds like you will have enough information available as to how the analysis was performed and could be updated so that an overall evaluation would be very helpful.

Thank you.

MS. COOPER: Yes.

MR. BLEY: This is Dennis.

MR. KURITZKY: Susan --

Go ahead, Dennis.

MR. BLEY: Okay.

Just a quick thing, I think it would be very, well, helpful, but also honest to at least have some statement of what the impact of not having brought it into current conditions might be on the results so that people don't over interpret the existing results.

That's all.

MR. KURITZKY: Okay, thank you, Dr. Bley, I took a note.

MEMBER ROBERTS: This is Tom Roberts.

Susan, I wonder if you could address the implication or evaluation you did of habitability in the various places since you're assuming actions you're taking in the control room, TSC, whatever locations the portable equipment in this model is being used?

MS. COOPER: Okay, so the -- that sort of plays into the slide that is up right now. The first part of the Level 2 HRA was what was referred to in the method as a screening process.

And in fact, a Level 2 PRA lead did most of this work to identify the plant conditions and so forth that would allow us to understand which of the various SAMGs were the highest priority and how the Westinghouse SAMGs worked. That's the only one that they're going to be working on.

And then, along with that, you know, some detailed tables that gave us timing of various things that were going on, including SAMG entry, plant conditions, and the environmental conditions and various locations throughout the plant, equipment availability, survivability, and stuff like that.

So, that was the hand off to the HRA analyst from the Level 2 PRA lead with some very detailed information on what was going on in time.

Now, with respect -- so, that fed into the formal HRA including what's listed on the slide as a feasibility assessment.

One of the -- which is the definition of which is borrowed from fire PRA, HRA guidelines, NUREG-1921, specific feasibility criteria, including habitability or environmental concerns for the action location and the travel path. So, that was definitely considered explicitly in the HRA.

Did that answer your question?

MEMBER ROBERTS: Partially. Were there cases where habitability concerns precluded a step in the SAMG that you would have otherwise accredited?

Or were there some that were close and it degraded the probability of the action being taken correctly?

MS. COOPER: So by the time the actual method was applied, I was no longer the HRA lead, and I don't recall any right now. I did look briefly through the quantification report, and I didn't spot anything.

What I will tell you is kind of a lingering question for one of the actions that we walked down at the plant site. That was use of a portable pump to feed the containment spray system from the yard outside of the aux building. And we were unable to find any information on what the environment would have been there in the yard, so there was a question as to whether or not that would have been a radiation problem.

So we did have some discussion about that.

I think it's in the report, that it might take some more time to get a radiation survey before they would go and start the action, but we did not -- we were not able to track that information down to know exactly what the situation would be.

But I will say, one thing that we -- that was done in this HRA approach for Level 2 is we said we're not going to take any timing constraints from the PRA as some sort of surrogate success criteria, or whatever. The HRA analysts themselves developed the times by which they thought the operators could complete the actions, and in general it was intended to be quite generous.

We did see some differences between how easy it was to walk through deployment of that portable pump in the walkdown versus the talk-through in the conference room. So we expected that they would have some difficulties that they would eventually overcome, but I would need more time.

So I don't recall if there were any that were precluded, but we did have some gaps in our knowledge as to whether or not some things might have to be performed somewhat differently.

MR. KURITZKY: Susan, if I could just -- and, again, I can't say definitively, but the whole idea, as Susan was mentioning earlier, that we had a screening process for determining which actions could be taken. So as part of that screening process, if there were actions that we felt the conditions were that action had to be taken, or in transit to that location would have been problematic, then they would be screened out of consideration for the level.

MEMBER ROBERTS: And part of the motivation for my question is there is a separate issue. There is the proposal to double the allowable deterministic control room dose, and I'm just wondering what the risk significance of that might be. The paper that proposed that says there isn't any because risk analyses don't model operator doses in the risk analysis, and it sounds like that may not be an accurate statement based on the work that Susan is describing.

And I was wondering if you had an overall perspective on whether there is a potential risk significance to doubling the deterministic allowed control room dose or whether that would just, you know, be a round off here.

MR. KURITZKY: So, and, Susan, I'll let you speak in a second if you want to.

But, Mr. Roberts, my response to that is we didn't -- and it's going to be one -- actually one of the examples they give for model uncertainty, if we have time to get there later.

But the -- we did not do a very detailed analysis of those environmental conditions for a number of reasons, which I'll explain later. But, so the level of resolution of our analysis might not be to the extent that we could analyze something like that with this -- with this particular model.

What you mentioned is something that theoretically would go into that, either the initial screening -- that's probably where it's most likely to happen, because if you have -- if you have the onsite radiological conditions, and you have a mapping of it, and say, okay, well, this level is too high now for them to take action, and those get screened out, you can see what the impact of not having -- being able to take those actions would be. But right now the resolution of our model I don't think is such that we would be able to evaluate the impact of that.

Susan, do you have anything else on that?

MS. COOPER: No. Although I will say that I don't think any of the actions that were addressed in the Level 2 HRA were taken in the control room.

Anyway, so just to conclude on this slide, the Level 2 HRA that was performed was a formal HRA application, including, you know, discussion of how the human failure events were defined, formal feasibility assessment, qualitative analysis, and then quantification. There were separate decision trees used for quantification for diagnosis and execution.

In both cases, there was an emphasis on whether there was existing guidance for performing the actions. In other words, if -- so in the SAMG space, if a particular SAMG said, "Look for ways to get water into the containment spray system." And as I was told by the SRO who was in the mini-E drill, he said, "Oh, well, those EDMGs are like little procedures that are already written up, so I thought we would go use one of those."

So if that's the case, then there is some -- you know, there is already something to work with, so the hierarchy for the -- for the diagnosis tree was whether that little -- that little set of procedure steps were -- and EOPs, we had higher confidence that they had been tested out and would work. EDMGs and the like were another level where there was some confidence that they had been -- had been tested or exercised.

And then of course if you had to make up something from scratch, that was the lowest level of confidence on whether they were going to be able to come up with a workable strategy. And the execution trees were similar, again, more looking at how much experience -- typically, the field operator would be doing this, and how much experience he or she had with actually implementing the procedure.

There is a paper from PSA 2015 that describes generally the approach, and also has an example of the diagnosis tree. I guess I don't -- Alan will have to speak to the actual Level 2 PRA report to say how much of the HRA is in that report that would be documenting the method and its application. I'm not as familiar with that.

So that's the short summary, I guess you could say, of the Level 2 HRA.

MEMBER DIMITRIJEVIC: Susan?

MS. COOPER: Yes.

MEMBER DIMITRIJEVIC: So I still see sensitivity that's in the reports, and that -- do you have any collection of the results of sensitivity events, if those actions were not considered?

MS. COOPER: No. I'm afraid I was not involved in that work. That would have been Don

Helton and Stacey Hendrickson, neither of which are available today. Maybe Alan would be able to remember something. I do not know anything about that. I was not involved.

MEMBER DIMITRIJEVIC: All right. So all of those actions, the goal is to prevent the containment failure, right? Given the amount either, you know, through the prevent containment bypass or containment failure, right?

MS. COOPER: Yes. Yes.

MEMBER DIMITRIJEVIC: And that --

MS. COOPER: Well, some of them are also for you know, scrubbing fission products also.

MEMBER DIMITRIJEVIC: Right. Yeah, to reduce releases, right.

MS. COOPER: Right.

MEMBER DIMITRIJEVIC: Okay. So, however, in this slide which we discussed so much in the beginning, because of those green numbers, there is something else which is very interesting, and that's that this containment is not performing greatly. You know, the condition of containment failure probability is very close to one, right?

MS. COOPER: Mm-hmm.

MEMBER DIMITRIJEVIC: I mean, it's

presented in some other results, not of this particularly, but we can see, you know, the difference between the larger things -- you know, the large releases and condition -- core damage frequency.

So I was wondering, are those actions mostly considered for preventing early releases or early containment failures? I was very interested actually in sensitivity analysis, and I saw some partial ones, so I was sort of like wondering what was importance of those actions.

MR. KURITZKY: Okay. Just -- sorry.

MS. COOPER: Go ahead, Alan.

MR. KURITZKY: Okay. So just -- I don't have the numbers off the top of my head, but in Volume 3C, which is the Level 2 PRA for internal medicine floods, I was going to mention actually on the last slide, there is an appendix -- I think Appendix C -- which is entirely devoted to uncertainty analysis.

And in there they have the results of many of the sensitivity -- or all of the sensitivity analysis we performed for Level 2. There is one where we I think raised all of the Level 2 HEPs by order of magnitude. And then we lowered them by an order of magnitude, so it gives you what the impact of that was.

And then, also, we did another sensitivity analysis where we considered additional actions that and I guess this is something I was going to talk about maybe on a different slide. But, again, because we used the seven-day -- we carried this interaction analysis out to seven days, but for the level -- HRA for the Level 2 space, we only considered one action in general, one action before vessel breach and one action at or shortly after vessel breach.

So then you have that whole other up to seven days, or however many days where you're -- where the action is progressing, but we're not considering any other attempt by the operators to do anything to prevent containment failure or mitigate the release.

And so we went and looked at several other actions that could be taken in that timeframe to see what the impact would be, and it was fairly substantial, if you credited those additional actions.

The main one was controlling containment pressure to avoid that overpressure failure, either by venting or by restoring heat removal -- containment heat removal, because, again, that long-term late overpressure containment failure was the big driver of this, and primarily because of station blackout contributions.

And so if you could take actions in that seven-day period to prevent that overpressure failure, you could definitely have a big impact on large release frequency and all the latent -- the latent cancer fatality risk metric and the other long-term non-early health effects metrics.

So there is discussion on raising or lowering the HEPs in that Appendix C to Volume 3C, and there is also discussion on the -- in the Level 2 portion of I think Volume -- the overview report for internal events and floods, Volume 3, so long as we have just three. I think they discuss also the impact of considering other actions in that seven-day period.

MEMBER DIMITRIJEVIC: Yeah. I think all of that is right, so the sensitivity said. And it didn't really sound to me anything alarming where I saw them, but now when I look at that slide which you presented earlier today, what I see is that you have -- that slide gave us the core damage frequency of the -- you know, the -- let's say for the -- without FLEX, 1.5E minus 4, and it gives us the large release frequency of 1.1E minus 4.

So that means that containment -- conditional containment of failure probability is very close to one. So I was just wondering how much those human recoveries actually help us there, so that's why I asked the questions.

MR. KURITZKY: And just to follow off that, the reason that the conditional containment failure probability is so close to one, or I think in the .7 range or .6 range, is because those, again, are station black -- non-recoverable station blackout sequences.

And so if nothing is done to ameliorate that, to prevent containment overpressurization, then eventually you're just going to just build up over time. You're just going to build up pressure in the containment. And even though it's a large dry containment, it's very robust. If we just keep building up the pressure from MC -- you know, from molten core concrete interaction, you're going to eventually just get an overpressure failure in most cases. So --

MEMBER HALNON: I just want to say, listening to all of this, I was trained as an SRO back in the '80s and '90s, and we wrote the SAMGs in the '90s, somewhere around there. And we knew all this beforehand. We knew that you had to maintain containment. We knew that during severe accidents you had to take actions to maintain those barriers and to

-- so what new insight did we gain that we didn't already know?

MR. KURITZKY: Again, that's something that we will probably more -- get in a more structured fashion when we do the summary NUREG.

MEMBER HALNON: Okay.

MR. KURITZKY: But for right now, there's just -- there's anecdotal things that come up. And, again, you know, many of these things that Dr. Bier mentioned, for instance, ISLOCA, something that we knew going in --

MEMBER HALNON: Yeah. We knew that.

MR. KURITZKY: Okay. So we get further confirmation. We get maybe further details. We might learn something that's different. In terms of risk, there may be things that engineering-wise or operational-wise we know that we would try and do these actions.

But what's the likelihood of success? What are the impediments? What's the -- you know, given that there are certain less-than-ideal conditions, what's the impact on the likelihood of seeing these things? And what, if anything, can we do if those things don't succeed? Are there other options?

So those are all thought out from a deterministic point of view already in the plants. Obviously, you know, we're just doing a study trying to evaluate the risk. What happens is the actual risk is all a function of how the plants are designed to operate.

MEMBER HALNON: Okay.

MR. KURITZKY: So we're looking at getting additional information that can help us going forward, either confirm what we are already doing or what the plants are already doing, or looking for other alternatives or understanding what's the quantitative impact received in risk space.

MEMBER HALNON: So, okay, I'll wait until Volume 1 gets written. I know it's been 12 years since we started this. Another decade to get to the next -- what is the next -- that's -- I apologize. That's not right. When do you think Volume 1 will be at least drafted?

MR. KURITZKY: Okay. So you don't have to apologize. I would love anybody to shout from the rooftops about that, because I have been fighting for about 10 years, 12 years, to have people dedicated to work my project instead of being pulled off to other projects. So, believe me, I feel your pain.

The intention is to get it done, as you saw before, in 2024, to get them all done. Whether we can meet that schedule, again, depends whether the people that are the key producers of this work are allowed to work on this project or they do other things.

Unfortunately, because these people have become very good, or they were extremely well thought of as agency experts, they are put on almost every issue that comes in.

MEMBER HALNON: And I recall you said earlier that Volume 1 would be the most focused.

MR. KURITZKY: Yeah.

MEMBER HALNON: So I'll --

MR. KURITZKY: That will be.

MEMBER HALNON: -- I'll save my non deterministic -- my deterministic mindset to that. It will --

MS. COOPER: Yeah. And if I could just add, from the HRA perspective, without having done this work, there would be a big, fat 1.0 certain failure for every human action in the Level 2, if we had not done this work.

Now, granted, some of the HEPs for human error probabilities for some of these actions are pretty, you know, high compared to what you might find in the Level 1 PRA, but they are not all -- they are not all, you know, .1 or something like that. There are real numbers in there.

And as Alan pointed out in the -- from his summary of what's in the appendices for sensitivities for Level 2, the HRA does have an impact on the results. So it would be a big difference, you know, as demonstrated with the sensitivities if the HRA values were different.

So being able to credit what may seem obvious to an operator, but, you know, the PRA/HRA analyst needs to have a very strong paper trail, if you will, to credit these kinds of actions. And so this is a significant -- significant breakthrough I think.

MEMBER HALNON: Okay. Thank you.

MS. COOPER: All right. I think it's back over to you, Alan.

MR. KURITZKY: Okay. Thank you. Thank you very much, Susan.

Okay. So next slide, please, Jonathan.

So I think we're running very short on time here, so I have a number of examples of model uncertainty that we don't necessarily have to get to.

But I do just want to go over the approach of our parameter and modeling uncertainty.

So very quickly, for parametric uncertainty, we handle that just like every other PRA generally does. We assign distributions to all of the basic events in the model, and we propagated those through and did Monte Carlo sampling to come up with the distributions.

One thing -- and in doing so, we also included distributions for the -- for the main FLEX events, so we assigned distributions to those, non-constrained, non-informative distributions for those, because we didn't have the data. But we also considered the state of knowledge correlation for those when you're sampling for similar components. So all that was rolled up into the parametric uncertainty analysis.

One thing that we did differently than many typical Level 2 PRAs is we directly linked our Level 1 event trees to our Level 2 containment event trees. So we were able to pass through, cut set information on certain industry distributions all the way through to the release category frequencies, so they got good distributions on the release category frequencies.

Going on to the Level 3 part, the consequence analysis, the only input in the consequence analysis that we actually sampled was the meteorological data, the weather. Everything else, the other inputs from -- go in the NACS (phonetic) were only treated as sources of model -- we identified model uncertainty for those.

So, but nonetheless, we did carry through the quantification of the uncertainty analysis through the Level 3, so that we were able to come up with complementary cumulative distribution functions, which are reported for all the risk metrics in the Level 3 reports.

We also came up with tables where we identify specific selected values of the different metrics and provide the mean, the 5th, the 95th percentile exceedance frequencies at those levels, like for instance for latent containment -- for latent cancer fatalities. You know, one fatality, 10, 100, 1,000 fatalities, always we provide the exceedance frequencies at 5th percentile, 95th percentile, mean.

One thing we did run into some difficulty with was we have some fairly high failure probability events. I mean, I'm talking failure probabilities of .6, .7, .8, et cetera, very high. So you had to be careful because if you have any type of a broader distribution on those, you're going to keep sampling above 1.0, which is obviously not something we can do.

Our code, SAPHIRE, will discard any samples that are above 1.0. But if you have these very high failure probabilities, you will get a lot of discarded samples which can affect the results. So we had to -- we limited the -- we used a threshold limitation on the -- on the error factor to make sure that you didn't have too many discarded samples.

The actual output -- while we consider the output distribution, the ratio of the 95th percentile to the 5th percentile is fairly tight for all the hazards, and when we calculate that -- and, again, I go back to my saying that I -- I don't put a lot of faith in parametric uncertainty. I'm more interested in modeling uncertainty. But, nonetheless, we -- the standard tells you to do it. We do it. Everybody does it. The ratio of the 95th to the 5th for the different hazards, as you see on the slide, range from four to 14. Four was for internal fires.

For internal events, it was about eight, the ratio from 95th to 5th. Looking at the results from NUREG-1150 for the three PWRs that were analyzed, their internal event range for the 95th to 5th, I think were like eight, 14, and 20, so this is in line with that, on the lower end, but definitely in line with what was obtained for the NUREG-1150 plants.

Much greater ranges for the PWRs in that study, I think partly because they had much lower frequencies of core damage. But in any case, for the PWRs, it was somewhat in the same range. So there is parametric uncertainty in how we treated it.

Do you want to flip to the next slide, Jonathan, so we can quickly -- so modeling uncertainty, to me, that's the big elephant in the room, or whatever it is. That's the thing that really, you know, is what we have to keep mind of. And I want to stress that though the modeling uncertainties are voluminous, there is many of them and they can be very impactful, that doesn't mean you can't use the results. It means you have to use the results in a smart fashion, and you use them in an appropriate context.

Okay. And so, but given that, we address modeling uncertainty like every other PRA does. We identify the key assumptions in those areas that are most uncertain. We use engineering judgment to help us determine whether we think these are going to be important.

And then we take the ones that we think are most important or particularly deal with some very -- an issue that is of much interest in the -- to the NRC or the technical community, and we perform sensitivity studies for those. And, again, those are one-off sensitivity studies. We don't mix and match different things to change at the same time generally.

We went and performed sensitivity studies for quite a number of them. Those that we identified as -- or that we thought would be important but we couldn't do sensitivity studies, either because of lack of resources or lack of information, we identify as candidates for future research.

The following slides will provide examples of each type, ones that we did sensitivity studies for and ones we just put in the future research bin.

But one thing actually that's not on those slides that I just want to mention as a very big source of modeling uncertainty is anytime that you bin something, for example, for seismic events, we have eight seismic bins. Obviously, earthquake -- based on seismic acceleration level.

You obviously can have unlimited set of earthquakes, from barely feeling it to when whatever goes on the top of, you know, Himalayas.

So we put them into eight bins, and you have a lower and upper peak ground acceleration for each bin. And so we select a single representative PGA to be used for the fragility analysis for that bin. So when we calculate the likelihood of components failing because of the seismic acceleration, we're not doing it for a whole distribution within that failure. We're doing it for a selected value.

The same thing for going to -- with these category frequencies. We carry all of the information through to the release categories, but in coming up with the source terms to represent each release category, we have to pick a specific MELCOR run that's going to have a set of source terms that we're going to use for the consequence analysis.

And that one set is being used for all the severe accident sequences that are in that release category bin. So those, by definition, whenever you're bidding things, you're going to have a lot of uncertainty there.

As I mentioned earlier, one of the other things, too, we looked at was the interfacing system LOCA frequencies, and we did an expert elicitation for that.

Just to go to the idea of where all this information is --

MR. BLEY: Alan?

MR. KURITZKY: -- I've been -- yes.

MR. BLEY: Yeah. Quick question. The way you stated that kind of bothered me. It sounds like we'd pick the bins and then we just took whatever happened rather than picking the bins to put together scenarios that were similar in the ways that matter for this category. Can you clarify which approach you took?

MR. KURITZKY: Thank you, Dr. Bley, for keeping me honest. I was shortcutting, yes. So whenever we do bin things, and this is for the release categories example, we are picking severe accidents that we believe all will behave similarly in terms of long-term severe accident progression and radiological release.

But given that, we have a finite number of bins. We have to keep it small enough to make the Level 3 analysis manageable. And so, by that nature, we are including sequences in the bins that do not -- are not all mirror copies of each other. So there are going to be instances where sequences are similar in very many aspects, but there may be some aspects where they diverge.

If they diverge enough and at frequencies great enough, then we may have to create another bin. But, again, we have 16 release categories already. Probably do not want to do too many more than that or you're going to get with an impracticable situation.

But, yes, we do bin them based on similarity of characteristics, how we expect release category space to impact source term, timing, and --

MR. BLEY: Which limits the uncertainty quite a bit.

MR. KURITZKY: Yes. Exactly. So I didn't mean to overstate the impact on uncertainty from the binning. But it just -- the binning, by definition, even with those constraints does -- is a definite source of uncertainty.

And it's demonstrated -- if you look in the Level 2 report, for instance, when 3C -- when it discusses source term selection, we go through a number of different MELCOR runs for each release category. And we have to pick sometimes between several different ones, decide which one we think does the best job of matching the breadth of sequences in that bin.

So you can get a flavor for some of the

variation when you look into that section of the report.

Okay. So, Dr. Rempe, this -- what time -- I have to wrap up by 10:25 or something? Is that the --

CHAIR REMPE: We still need to have public comments, and we were hoping that this part -- presentation would be done by 10:30. I'm --

MR. KURITZKY: Okay.

CHAIR REMPE: -- not going to hold you to it. We do have letter writing after this.

MR. KURITZKY: Okay.

CHAIR REMPE: But please try and wrap up.

MR. KURITZKY: All right. Yeah. So that's essentially the case. I just want to mention on this slide one last thing.

CHAIR REMPE: And I do realize it's the members' fault --

(Laughter.)

MR. KURITZKY: Thank you. Group exercise.

So, anyway, I kind of alluded to this before I think. So all the modeling uncertainty information, because there were so -- so many areas of modeling uncertainty, oftentimes we'll have a single section in the report that covers the uncertainty or the modeling uncertainty, an example being buying a 3C to Level 2 PRA for internal medicine floods.

There is an Appendix C that actually covers it all very nicely. And as I mentioned, there's a section in -- a summary section in Appendix C which does a nice job of summarizing the modeling uncertainty in that appendix.

Other cases like the Volume -- the Level 3 reports, there's several categories of max inputs, and there are so many uncertainties associated with each it made more sense to discuss those uncertainties within each section where we discuss those different max input -- categories of max input parameters.

So, for instance, Volume 3D, Section 3, you'll see them broken out separately by section. So, again, depending on the report, the volume of information, the number of uncertainties, they may be in one section or one appendix, or they may be distributed in different sections in the report.

Next slide, please?

For the last two slides, one gives examples of things that we addressed for sensitivity analysis, the other ones we did not. This reaction progression time, we have already talked about the seven-day thing. I don't need to -- I don't think I have to elaborate any more on that.

Another one actually we ended up hitting -- talking when we're discussing some other question, we looked at the potential for other actions in that seven-day period that weren't in the base case model. And we saw that -- that there was definite additional benefit for preventing a large release if you considered some of these actions in the later timeframes.

And, again, that was -- that essentially was controlling overpressure. That was containment venting or getting containment heat removal restored to prevent that overpressure failure. And if you coupled that with precluding combustion, then you really had an even bigger.

The biggest one I want to mention here is the low-dose cancer risk estimation, because use of a -- of a low-dose truncation value in the qualification of latent cancer fatality risk, has a definite impact. If you limit -- only include doses that if you -- or if you exclude in that quantification, you exclude doses that are comparable to what you would just get from natural sources.

And if you do that, you have a much greater latent cancer fatality risk because the bulk of that risk is coming when people move -- long after the accident people come back and spend the rest of their lives with very low doses in the background, additional doses in the background.

And so, statistically, you will build up a number of latent cancer fatalities. But if you -- if you don't include the ones that are in the same ballpark as natural background radiation, then you greatly reduce those.

MEMBER PETTI: Alan, what was the cutoff level?

MR. KURITZKY: In our -- we used something from a 2010 health physics study paper, and so our cutoff I believe was in order to be considered you had to have at least five rem in one year, and at least 10 rem cumulative. You had to get a least five -- five rem in one year after the accident, same year after the accident, and 10 -- and at least 10 rem.

MEMBER PETTI: So these are much higher than actual background seen in elevated cities around the

MR. KURITZKY: Yeah. I mean, the -- I can't speak to that. I think they are somewhat tied to like the EPA PAGs.

MEMBER PETTI: Yeah. Yeah.

MR. KURITZKY: But you know a lot more about it than I do, so --

MEMBER BALLINGER: This is Ron. When you say five rem in a year, for radiation workers, 5N minus 18, that's the number -- that's the number I keep in my head from a long time ago as not being -- not resulting in a statistically increased cancer risk. So you're probably right.

MR. KURITZKY: Again, in my specialty, but that -- yeah, that's --

MEMBER PETTI: No, not that Alan says it. I remember reading it. You know, it was tied to EPA PAGs.

MEMBER BALLINGER: Once in a lifetime is 25.

MEMBER PETTI: Which makes sense. Good. Thank you.

MR. KURITZKY: Last one on this. I just want to -- I only want to mention it because it has a big impact on early fatality risk, goes back to the numbers we were talking about before.

So remember early fatality risk was 10 to the minus 13, very low number. So one thing that we saw that had a very big impact was that early fatality risk for seismic events, we already considered degraded evacuation for seismic and high-wind events. We have a degraded evacuation model and -- but we wanted to also look at what happens if the evacuation times were even greater or the shielding was less effective than even when we considered our base case degraded evacuation model.

And we saw that in fact it was a very substantial impact on early fatality risk when we considered longer evacuation delays and more degraded shielding. Doesn't have much of an impact on latent cancer, because I just said that that happens much later, but the early fatality risk was multiple orders of magnitude higher if you -- if you had that, you know, for instance a 48-hour delayed evacuation and much-degraded shielding.

Next slide, please?

There's a question whether my voice will give out or the time will give out first.

So here is just a few examples of things that we -- that were canceled for research we did not pursue. One of them got brought up before I think by Mr. Roberts about the environment -- the conditions under which we would take action.

So that's something that we treated fairly simply in the study, because of limited information, because of the level of detail of our accident management analysis, and obviously resources in the projects. So we didn't delve into it in too great of detail, but enough that we got some reasonable results for use here. But that's something that could definitely benefit from much more detailed analysis.

The containment failure paths, one of the major assumptions that we made for that overpressure failure, the one that seems to drive many of the results, is that when that containment failed, it would fail into the tendon gallery.

So we did structural analysis that showed there were a couple of different areas that were very likely to have -- be the weak points. One was the tendon gallery, but there is also it could fail into the auxiliary building. The tendon gallery gave worse results, because that ends up then going out to the environment. In the auxiliary building, you get a little bit more shielding and a little bit more reduction in source term, or definitely more reduction in source term.

So, have you picked for those to go into the aux building, or if we picked -- they'd have to do the one we have to -- you would see a definite impact on the results. That's an assumption that makes a big difference. We can identify that, but that's something that we didn't further analyze.

Also, just the shape and size and the geometry of various failures, containment isolation failure, so it -- where distribution comes from seismic event that can structurally damage the containment isolation system. How are those leakage paths or containment penetrations physically damaged? So that can impact how much gets out, what kind of source term you have.

And the last few are just things from the Level 3 model. They're not even the -- Keith will yell at me for picking those, not better ones, but they were examples of just things in the Level 3, the max analysis, where we have uncertainty, which we just identify but we haven't done anything in this failure to quantify.

And with that, the last slide just goes to the issue that came up in the subcommittee meeting about where we could find all of this information. I kind of talked about this already. Depending on the nature and the amount of the information, you'll find it either in a dedicated section or appendix in the report or it will be spread in different sections.

As part of the summary NUREG, we will

attempt to try and package some of that together in an organized fashion, but it's only going to be -- it's not going to be something that's going to make anybody smile broadly, because it's going to be limited in what we can do, just because there is so much information.

And there's no real way to rank like this particular model uncertainty for Level 1 PRA for seismic events versus this Level 2 PRA for internal events, this issue. There is no, you know, rubric which -- to kind of really compare them very well. So it's going to be a lot of judgment call pulling a few key things together. But that is our intention for the summary NUREG.

And that's the only thing I had, so --

MEMBER PETTI: Alan, just for the record, I looked up radiation dose in Denver is about one rem per year for people living in Denver, compared to the average American. And the average radiation dose for a pilot or an airline employee that flies all the time is three rem per year. So just some numbers for that.

So the cutoffs that you guys were using were, you know, previous --

MEMBER BROWN: Did they give cancer fatality rates for those numbers?

MEMBER PETTI: The only thing I saw was that there is no increase in cancer risk for people living in Denver versus other areas. I can't find anything about whether there's increased cancer risk for airline pilots. But I would need to look more.

MEMBER MARCH-LEUBA: Going back to the model uncertainty -- and this is not a question, just something I want to place on the record, I didn't see any emphasis on what they call completeness in model.

We forgot to model the large tsunami or for this year my heart is we never include cybersecurity in the model. And, in my opinion, it's the largest risk to reactors in 2023, and it will be even greater in '24 and '25.

So that's really impossible to quantify, but that is the largest source of uncertainty. What did I forget?

MR. KURITZKY: Thank you. Good comment.

MEMBER MARCH-LEUBA: Because I'd like to place on the record, the numbers -- the risk numbers you are calculating are non-conservative, lower bound estimates of the risk. The risk can only be higher than the number you calculate, because you forgot something, which will increase it. So I keep saying that, and my PRA friends keep getting upset, but this is the truth.

MEMBER DIMITRIJEVIC: Well, we don't need to get upset because, I mean, you are totally right. We -- I am a little upset that you don't look at dose uncertainties, you know, in the thermal hydraulics. In Level 2, they are also incredibly high.

There is also so much limits, you know, that, Alan, what we can do and report in uncertainties. And it would be really, you know, the great benefits from this project if those are identified. You said something in the -- in the -- you know, when we were discussing the small numbers, what you said that, you know, the only uncertainty which we can calculate is parametric uncertainty, and you are not big fan of that and neither am I.

However, when it comes to the modeling uncertainties, the phenomenological uncertainties, the deterministic status uncertainties, we don't really have a good way to report that. And we definitely don't have a good way to report incompleteness uncertainties because we really -- don't really know what we are missing until we realize we are missing it.

So, and all of the sensitivity analysis and modeling uncertainties which identify something important, there is no way we can plot them. So, for example, even when we can start with a simpler -- like a state of knowledge that if you -- you concede that as soon as your point estimates are close to your mean value in -- that implies that almost all parameters are treated as independent, which is not true.

And the problem with that is that, you know, often those same components are in common cause groups, and then that's -- that they don't allow you to treat that or state knowledge appropriately. So even in these simple parametrical study we have issues on reporting, and you definitely -- you know, you didn't show us any -- you told us the ranges, but you didn't show us any numbers. Like, for example, do we see the bigger uncertainty ranges in reporting the Level 2 result?

MR. KURITZKY: Yeah. The Level -- excuse me, in Volume 3C and Volume 4D, and we have -- we have tables of all of the uncertainty issues we should follow with these categories. As I said, there's 16 of them. So there's -- I mean, it's a lot of information. So, yeah, no, I did not provide any -- again, my understanding was we were -- I was supposed to limit what numbers I showed at the presentation. All those numbers are in those reports.

MEMBER DIMITRIJEVIC: You would expect, as you said in the regular discussion in the beginning of this, that you see much higher ranges, for example, in the Level 2, right? And you definitely will expect to see much huger ranges in Level 3, and we don't see those.

My question is: so, obviously, you know, this is something which is -- I am not expecting this study to solve, but at least to point to the needs for the much further research in this area. How can we report those modeling uncertainties, incompleteness uncertainties? How can we involve them in actually reporting these, meaningfully reporting the results?

So whatever you have, there is a lot of very valuable information, and I saw that you did something in the Level 2 with combining these deterministic and the -- and also in the groupings and everything. I know -- and I look at these happenings very carefully. It's very difficult to look at data and say, "Oh yeah. This is the issue."

So, I mean, I certainly hope that a lot of the good things will come out of the -- of your experience in analyzing and reporting uncertainties.

MR. KURITZKY: Okay. Thank you.

MEMBER DIMITRIJEVIC: I mean, just showing the graphs and numbers, you know, it's not really make everybody saying, ah ha, oh yeah, that's what that means. You know? Everybody is going to look at a number and say, all right, I mean, another factor of the vote, it's no big deal. That's not true. That other factor is totally not true, so -- okay.

MR. KURITZKY: Thank you.

MEMBER PETTI: Yes. I wanted to get some things clear in my mind. I wrote some things before subcommittee, and I want to make sure they're clear in my mind as we go into letter writing.

I always have this belief that external hazards tended to dominate the risk over internal events, just because good engineers can engineer away a lot of issues. Is that still a fair statement? I mean, I understand there's bypass sequences that are there, but is that --

MR. KURITZKY: The results for this -- again, for this event, we show that internal events in the base case are one of the major triggers, but it's on par with internal fires. Seismic and high wind were lesser at this plant.

When you consider FLEX, internal event goes down further because it's primarily station blackouts in the FLEX knocks that (audio interference). We also give more credit for FLEX under sunny day conditions of an internal event in the conditions of the plant -- or the first time they experience after an earthquake or --

MEMBER PETTI: But other PRAs show something different, right? That external are more risk-significant than internal?

MR. KURITZKY: I don't want to speak to it, because I don't remember the exact numbers. In the -- in a moment, we're going to dig into some other --

MEMBER PETTI: That's -- these are some of the things that I think, yeah, it would be really --

MR. KURITZKY: Right.

MEMBER PETTI: Second, just on the whole FLEX strategies, you only did Phase 1 and 2 in FLEX, right? You didn't do Phase 3, which may really change the risk profile or -- I just worry about people looking at it and -- because I did it before. FLEX didn't seem to help a lot, but Phase 3 FLEX is not there. And so to have a -- to make sure you don't misinterpret, that that's a very important piece of the overall FLEX strategy. So --

MEMBER BALLINGER: Yeah. We visited Phoenix I guess, the Arizona -- the Arizona thing, and

I was asking the folks out there, you know, that Phase 1 -- 1, 2, and 3, and they told us that more than likely they would be supplying stuff right away.

So Phase 1, Phase 2, Phase 3 would -- is just -- you know, it would be compressed. So that would have an enormous effect, I think.

So depending on how fast they brought other equipment onsite, it could have an effect -- it would not have an enormous effect because -- a couple of reasons. One is we are only taking analysis out for a certain number of days. The core damage -- remember, FLEX is primarily interested in preventing core damage, not mitigating the release. Core damage is occurring much more quickly. It's occurring in the first X number of hours after the initiating event.

So you can get more FLEX equipment in there, but core damage has already happened. So where that extra FLEX equipment really comes into play is to extend the life of FLEX. In other words, if you're using FLEX equipment to keep the core cool, and you start to run out of power, this or that, you get more diesel generators, you get more pumps, more fuel, whatever. You get more resources, so you can keep going.

We have always stopped the analysis. We

either had core damage by then, in which case it's not helping, or we don't have core damage, but we're not we're not considering that long timeframe for core damage. So we've already said you're okay, so it would not really have any impact. It personally would have no impact on the actual analysis.

But it's needed if you are relying on FLEX for the long term, but it will not impact, I don't think, the estimation of core damage frequency or the ensuing, you know, risk metrics.

MEMBER PETTI: And then my third comment is more for the other members. You know, as the advanced reactor guy, I think about and look at all of the events, and you think of how many of them are driven by station blackout and heat removal, right? And heat removal will be passive in most of the advanced systems, and they will not require electric power to execute their safety function.

So it's really going to be interesting when we see, you know, a more complete PRA of one of the advanced systems, because I think it's just going to look so different than what we see here. I think it's going to be an interesting comparison once we get there.

MEMBER BALLINGER: Thanks.

MEMBER DIMITRIJEVIC: Alan, Dave just reminded me of something, which I -- I mentioned in our subcommittee meeting, and I want to bring it over here. You know, your FLEX -- FLEX case includes also something which -- and this is why when I was giving you example of the containment performance I was using the circa 2012 case -- includes not just the FLEX strategies but also improval [sic] in the seals, which is extremely important for four-loop Westinghouse, because risk in the four-loop Westinghouse plans before, you know, the improvements to the seals that was dominated by seal LOCA and loss of component cooling water, you know, that you lose cooling to the seals.

So it's not -- you said that this risk level is dominated by loop, but that is after the seals are improved. Before the seals are improved, I am almost sure that the seal LOCA was one of the main contributors. Is that a true statement?

MR. KURITZKY: Yes. Seal LOCAs are definitely one of the major contributors. But, remember, seal LOCA is also an outcome oftentimes from the station blackout, too. But those improved seals, we did a sensitivity study on that, in the Level 1, specifically just for the seals, and it reduced CDF by around 14 percent. So it's not going to --

MEMBER DIMITRIJEVIC: So, therefore, that FLEX things also -- you know, involves this other case, this case. Also, the last time in the subcommittee meetings, you said that this prolonged operation of turbine-driven auxiliary feedwater, which I was not considering FLEX case, you said that may -- it may be considered FLEX case.

So is this prolonged operation of turbine-driven auxiliary feedwater, does that have something to do with FLEX or this is independent?

MR. KURITZKY: Totally independent. It's just something that we did not credit in the initial model. And so when we went to do -- we gave some part -- we gave some credit for it in the Level 2, in terms of extending the time for it -- for reaction progression, but in the Level 1, we thought it was too unreliable, and so we did not credit it.

But we felt in the FLEX -- when we did the FLEX modeling to get things more realistic, since already the FLEX was going to have a fairly high failure probability, on par with the continued turbine-driven aux feed -- if we're going to credit one, we'll credit them both, but, again, they both have a fairly high failure probability.

But because you just need one or the other, the combination gets you down to a relatively low number, like in internal events we have a .3 failure probability of reach. So essentially you have to fail both. You have a 91 percent chance of success of either one or the other, so it has a fairly significant impact on the station blackout sequences. Less so for some of the internal -- some of the external hazards where we give less credit from FLEX, but, you know --

MEMBER DIMITRIJEVIC: So factor P, which you use to measure, you know, sensitivity, and we talk about broad distribution, it's combination of the FLEX strategy and the -- crediting this action on auxiliary feedwater, right?

MR. KURITZKY: Yes.

MEMBER DIMITRIJEVIC: Turbine driven.

MR. KURITZKY: Yeah.

MEMBER DIMITRIJEVIC: So, actually, there is -- I just want to say that the FLEX sensitivity case is not -- it may be less than 50 percent FLEX. It's mostly -- it's both seals and this auxiliary feedwater. By the way, is this auxiliary feedwater human actions? That's a part of your regular HRA, right?

MR. KURITZKY: Yeah. For the extended turbine-driven aux feed, that's all -- that's really all human accident, and it's -- and it's a very dicey human accident because they are manually controlling those -- that turbine-driven pump without the benefit of essentially controlling -- you know, without AC and DC power, so they're kind of flying blind. So that's why we didn't credit initially, and we give it a very high failure probability when we do this analysis.

But you're right. If we do not consider that, the impact of FLEX is much lower. Instead of having a .09 failure probability, it's a .3. But, again, remember, we used that .09 failure probability, and then we showed how it compared to whether we -- if we used higher or lower values of P, and it didn't make that much difference on the -- on the core damage profile.

But if we only did consider FLEX and didn't consider the turbine-driven aux feed, extended turbine-driven aux feed also, then that would be a different case. And maybe we would have had to do a little more rigorous analysis of the FLEX failure probability because it might have had, you know, more -- you know, the value we pick would have to be more influential.

MEMBER DIMITRIJEVIC: So FLEX here is just basically the cavity of offsite power. Is that what the FLEX is here?

MR. KURITZKY: Well, it's not -- it's functionally similar, but it's not actually -- it's not recovering actual offsite power. You're -- what the FLEX is doing is bringing in what -- Phase 1 you actually have the strategy. You're stripping down your batteries to give it -- to extend your battery lifetime maybe two or four hours.

MEMBER DIMITRIJEVIC: Right.

MR. KURITZKY: To 12 hours. But then you're bringing in a portable diesel generator and a pump, so that you can run things, even though you don't have offsite power.

MEMBER DIMITRIJEVIC: Yeah. I mean, the recovering power. That's what I --

MR. KURITZKY: Recovering, yes, recovering power.

MEMBER DIMITRIJEVIC: So did you consider dependency of that on the time an ELAP (phonetic) is declared? I mean, do you have a different timeframe when was -- to declare ELAP in one hour I think and/or four hours or something? And then I was wondering, is there dependency on the human actions? Is that dependent of the timeline of declaring ELAP? That was one of my questions.

My other question was concern about this important action on the -- keeping auxiliary feedwater operable for the long time with no -- is this the local action? How does he control those valves bringing steam to the turbine? I mean, how is this action possible without AC and DC power? That's what my actually concern was, but that's an important part of this FLEX activity, but even it's not FLEX.

MR. KURITZKY: Okay. So, first, I remember now the first part of your question -- I'm getting too old. I'm sorry. What was the first part again?

MEMBER DIMITRIJEVIC: First part was the dependency of the operator action on the time of declaring ELAP and --

MR. KURITZKY: Okay.

MEMBER DIMITRIJEVIC: -- my second question is on this controlling the turbine-driven pump.

MR. KURITZKY: Now I forgot the first one again. No, I'm just kidding.

(Laughter.)

MR. KURITZKY: So, yeah, in terms of the

dependencies -- our level of analysis didn't go into a lot of detail. So we're not actually doing any type of HRA where those dependencies would show up. We've picked a value of .3. That covers human actions and equipment failure and severity. Coarse number, at least as picked by engineering judgment, and we've demonstrated that it didn't make that much difference, and so we could live with it. But that's -- but that -- so it doesn't go to that level of detail.

The second item -- what was the second one?

MEMBER DIMITRIJEVIC: Second one is, how does the -- how does he control this turbine-driven pump from being in operation for long time? For such a long mission time with noise in DC? I mean, just like I am totally mind-boggling. I would not credit that, so if you can just tell me how -- because you didn't include the equipment there. How does he control the steam supply to the turbine? That's what my question is.

MR. KURITZKY: So he is mainly controlling the governor valve to control how much steam goes in. And that's the reason why we didn't give it credit initially and give it very -- you know, very modest credit now in the sensitivity analysis, because he is manually controlling -- or they are manually controlling the steam flow in, and they can underfill or overfill the steam generator.

They can flood the input -- the steam inlet line to trip off the turbine, so there's -- it's very dicey stuff, and they're doing it manually. And probably a very limited local indication of anything at that point, because (audio interference) power.

But you did bring up this -- the long-term, you know, I don't know, because that they can theoretically do without power, so it's dicey. When it comes to having to refill, like, for instance, under normal conditions, we did add events in our event trees to consider long-term cooling, because in the case of RCPC LOCAs are small LOCAs.

You would actually keep going on for many hours, not just 24, and so we included actions in the event tree to get charging back or to bring more water for the aux feedwater. But under the conditions of station -- of that complete blackout, not just station blackout, but all loss of AC and DC, I don't know how easy it would be to get -- to make up or -- once you used up whatever was in those tanks.

But the assumption being over those several days you will come up with something to open the necessary valve, in other words, manually overriding the valves or lining up some alternative source. But, again, the analysis doesn't go into that level of detail.

MEMBER DIMITRIJEVIC: Okay. All right. Those were my inquiries about it. Okay.

CHAIR REMPE: Okay. So, at this time, thank you very much for your presentation and your responses to our questions and comments.

I think we need to open the line, which in today's world means just unmute yourself if you're a member of the public who wishes to make a statement at this time or a comment. Some folks may have to hit star six if you're on the phone. And I'm not seeing any hands up or anyone trying to make comments.

So, at this time, I'd like us to take a 15 minute break approximately. So why don't we come back at 10 after the hour, and we'll -- I believe you have a draft letter to read in, right, Vesna?

And before we take the break, though, I'd like to tell the court reporter that I'm going to be asking him to take off for the rest of the day, but to come back at 8:30. Okay?

(Whereupon, the above-entitled matter went off the record at 10:53 a.m.)

Level 3 PRA Project Briefing for Volumes 3 and 4

Advisory Committee on Reactor Safeguards

November 1, 2023

Alan Kuritzky
Division of Risk Analysis
Office of Nuclear Regulatory Research
(301-415-1552, Alan.Kuritzky@nrc.gov)

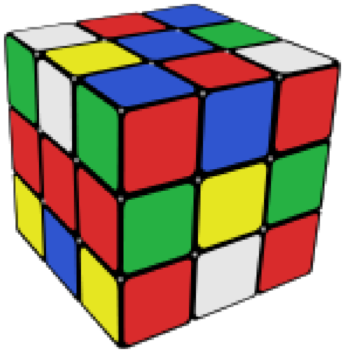
Susan Cooper
Division of Risk Analysis
Office of Nuclear Regulatory Research
(301-415-0915, Susan.Cooper@nrc.gov)

Outline

- Background
- L3PRA project public reports
- Summary of results
- Reactor at-power PRA preliminary insights
- Post-core-damage HRA
- Uncertainty analysis
- Report road maps

Background

- In a staff requirements memorandum (SRM-SECY-11-0089) dated 9/21/2011 the Commission directed the staff to conduct a full-scope, comprehensive site Level-3 PRA
- Reference site
  - Two Westinghouse 4-loop PWRs with large, dry containments
- Radiological sources
  - Reactor cores
  - Spent fuel pools
  - Dry cask storage



- Project scope
  - All reactor modes of operation
  - All internal and external hazards (excluding malevolent acts)
  - Level 1, 2, and 3 PRA (full consequence analysis)
  - Integrated site risk

Level 3 PRA Project Public Reports

Summary (Vol. 1)	Back-ground (Vol. 2)	Reactor, At-Power, Internal Events and Internal Floods (Volume 3)				
		Overview-IE/IF (3)	L1-IE (3a)	L1-IF (3b)	L2-IE/IF (3c)	L3-IE/IF (3d)

Reactor, At-Power, Internal Fires and External Events (Volume 4)					
Overview-F/S/W (4)	L1-FIRE (4a)	L1-SEIS (4b)	L1-HW/OH (4c)	L2-F/S/W (4d)	L3-F/S/W (4e)

Reactor, LPSD, Internal Events (Volume 5)			
Overview-LPSD (5)	L1-IE (5a)	L2-IE (5b)	L3-IE (5c)

Spent Fuel Pool (Volume 6)			Dry Cask Storage (Volume 7)	Integrated Site Risk (Volume 8)
Overview-SFP (6)	L1/L2 (6a)	L3 (6b)	L1-L3 (7)	L1-L3 (8)

Preliminary Schedule for Releasing Draft L3PRA Reports for Public Comment

- Reactor, at-power, internal events and internal floods **(Vol. 2 and Vols. 3x, 3a-3d) (4/22/2022)** **– comments resolved and currently with ADM for final publication**
- Reactor, at-power, internal fires, seismic events, and high winds **(Vols. 4x, 4a-4e) (8/18/2023)** **– comments received and currently being reviewed**
- Reactor, low-power and shutdown, internal events **(Vols. 5x, 5a-5c)** **(Q2-2024)**
- Spent fuel pool, all hazards **(Vols. 6x, 6a-b)** **(Q3-2024)**
- Dry cask storage, all hazards **(Vol. 7)** **(Q1-2024)**
- Integrated site risk **(Vol. 8)** **(Q4-2024)**
- Summary report **(Vol. 1)** **(Q4-2024)**

Summary of Results (All Hazards Combined)

Risk Metric (per reactor-year)	QHO or Subsidiary Risk Metric	Circa-2012 Case	2020-FLEX Case
Core damage frequency	**1E-04**	1.5E-04	**9.3E-05**
Large early release frequency	**1E-05**	1.9E-06	**1.3E-06**
Large release frequency	N/A	1.1E-04	6.7E-05
Individual early fatality risk	**5E-7**	7.5E-13	**6.6E-13**
Individual latent cancer fatality risk	**2E-6**	6.5E-08	**4.0E-08**

Reactor At-Power PRA Preliminary Insights (1 of 4)

- Combination of reference plant design and site location has substantial margin to the QHOs when considering all hazards combined, though the margins are noticeably less for the surrogate risk metrics of CDF and LERF
  - Extremely low likelihood of early fatality risk because of the following factors:
    - very low frequency of bypass events (ISLOCA or SGTR cases) that would generate relatively large and fast releases
    - relatively low frequency of adverse meteorological conditions (primarily stable, low wind speed conditions)
    - very sparse close-in population, which limits likelihood of wind blowing in direction of a populated sector very close to the site
    - low likelihood of delayed and/or slow evacuation of populations toward which winds are blowing
  - Low likelihood of latent cancer fatality risk because same factors above also lead to low exposure in early phase and effective protective measures limit late phase doses to no more than long-term habitability criteria

Reactor At-Power PRA Preliminary Insights (2 of 4)

- Offsite public risk metrics related to early health effects primarily result from:
  - ISLOCAs
  - ATWS leading to an unscrubbed PI-SGTR, with one or more secondary-side relief valves open
  - Post-core-damage TI-SGTRs

Reactor At-Power PRA Preliminary Insights (3 of 4)

- Offsite public risk metrics other than those related to early health effects primarily result from:
  - Unscrubbed, late containment failures due to long-term quasi-static overpressure
  - Unscrubbed, containment failures hours after vessel breach due to global deflagration or detonation
  - Unmitigated containment isolation failure (primarily for seismic events)
  - Post-core-damage TI-SGTRs (primarily for land contamination risk)

Reactor At-Power PRA Preliminary Insights (4 of 4)

- Selection of 7-day severe accident progression analysis time significantly impacts evaluation of offsite public risk metrics other than those related to early health effects
- Radiological release category involving unscrubbed, late containment failures due to long-term quasi-static overpressure (RC-LCF) is a major contributor to latent cancer fatality risk
  - Frequency of RC-LCF is significantly reduced for shorter analysis times
  - Action taken to prevent containment overpressure failure in ~2 days after accident initiation can prevent a large release
  - Level 2 PRAs that only model severe accident progression for 48-72 hours after accident initiation may significantly underestimate plant risk
- Radiological release category involving unscrubbed, containment failures hours after vessel breach due to global deflagration or detonation is also a major contributor to latent cancer fatality risk
  - Combustion is treated as a stochastic (vs. deterministic) process

Post-Core-Damage Human Reliability Analysis (1 of 2)

- Post-core-damage (Level 2 PRA) human reliability analysis (HRA) differs from traditional Level 1 PRA/HRA because:
  - the actions are based on general guidance in SAMGs, rather than very step-oriented procedures like the EOPs
  - there is less training and experience for the operator decisions and actions modeled in Level 2 HRA/PRA than for Level 1 HRA/PRA
  - there is not necessarily one specific action to take; rather, the staff has to choose from a variety of potential actions
- Features of approach in Level 3 PRA project:
  - Based on reference plant procedures, training, interviews, and walkdowns, as well a "mini-E drill" conducted by the reference plant in 2012 (i.e., very plant-specific)
  - Uses Gary Klein's naturalistic decision-making approach and concept of "team"

Post-Core-Damage Human Reliability Analysis (2 of 2)

- Features of approach in Level 3 PRA project (cont.):
  - Detailed screening process performed by the Level 2 PRA lead that assessed expected plant conditions for each defined scenario to determine:
    - Which SAMG was the highest priority
    - Timing of SAMG entry, various plant conditions (e.g., vessel breach), environmental concerns (e.g., habitability), equipment availability and survivability, etc.
  - Formal HRA including:
    - Human failure event definition
    - Feasibility assessment
    - Qualitative analysis
    - Quantification
  - Separate quantification decision trees for diagnosis and execution that assess information availability, quality of procedure support, etc.

Parametric Uncertainty

- For the Level 3 PRA project, parameter uncertainties were propagated through the linked Level 1 and Level 2 PRA models using a Monte Carlo approach.
  - For Level 3 PRA, only meteorological data was sampled.
- State-of-knowledge-correlation between event probabilities was accounted for in the quantification.
- An error factor threshold was applied throughout the L3PRA project for basic events with very high failure probabilities to avoid excessive discarding of samples.
  - The threshold values are intended to preserve the mean value and anchor the 95th percentile to a probability of approximately 0.95.
- The range of the output distribution (95th/5th) for all hazard categories is relatively tight, ranging between approximately 4 and 14.
- Complementary cumulative distribution function (CCDF) curves that illustrate the uncertainty in the frequencies of each risk metric are provided in the Level 3 PRA reports.

Modeling Uncertainty (1 of 3)

- To address modeling uncertainty in the Level 3 PRA project, key assumptions were identified for each PRA model.
- The impact of these key assumptions on the results was assessed through engineering judgment.
- To the extent practical, sensitivity analyses were performed for those assumptions believed to be most important to the results.
- The key assumptions that were not subjected to sensitivity analysis were identified as candidates for future research.
- One area of uncertainty (ISLOCA frequencies) was addressed through expert elicitation.
- For some reports, modeling uncertainty is addressed in a dedicated report section or appendix (e.g., Volume 3c, Appendix C); in other cases, it is addressed in multiple subsections (e.g., Volume 3d, Section 3).

Modeling Uncertainty (2 of 3)

- Examples of modeling uncertainties addressed by sensitivity analysis:
  - *Severe accident analysis progression time* – Reducing analysis time from 7 days to 2 days does not impact LERF or early fatality risk, but significantly reduces LRF and latent cancer fatality risk
  - *Credit for post-core-damage operator actions during an SBO and after vessel breach* – Does not impact LERF, but significantly reduces LRF (greatest reduction in LRF occurs from recoveries related to controlling containment pressure, with additional benefit seen if this is combined with controlling combustion)
  - *Low dose cancer risk estimation* – Use of a low dose truncation model (as opposed to the LNT model) significantly reduces latent cancer fatality risk
  - *Seismic impacts on evacuation modeling* – Early fatality risk from seismic scenarios is highly sensitive to the assumptions regarding evacuation delays and shielding factors; only limited impact on latent cancer fatality risk

Modeling Uncertainty (3 of 3)

- Examples of modeling uncertainties recommended as candidates for future research:
  - Further investigate treatment of equipment survivability and instrument degradation in severe accident environments
  - Better characterize containment failure path (e.g., nature of failure, location, and size)
  - Better characterize possible seismic containment failure modes, particularly regarding the size of the leak path involved in seismic isolation failure
  - Examine influence of decontamination plan (levels and unit costs) on dose and cost results
  - Examine effect of updated methodologies for developing shielding factors when current research is completed
  - Investigate effect of MACCS modeling of intermediate- and recovery-phase relocation and habitability decision-making

Reactor At-Power PRA Road Maps

- The Level 3 PRA project will ultimately consist of approximately 20 reports.
- Each report contains detailed discussions of important technical issues, assumptions, modeling uncertainties, sensitivity analyses, and candidates for future work.
- Due to the sheer volume of information, these discussions are often provided in multiple report sections.
- The final summary NUREG report will attempt to gather and organize some of this information.

Back-Up Viewgraphs

2020-FLEX Case Results Level 1 PRA (1 of 4)

CDF by Hazard Category

Hazard Category	Circa-2012 CDF (/rcy)	2020-FLEX CDF (/rcy)	CDF Reduction
Internal events and floods	6.47E-05	2.67E-05	59%
Internal fires	6.14E-05	5.34E-05	13%
Seismic events	1.08E-05	8.49E-06	21%
High winds	1.38E-05	4.85E-06	65%
Total	**1.51E-04**	**9.34E-05**	**38%**

Level 2 PRA Results (All Hazards Combined)

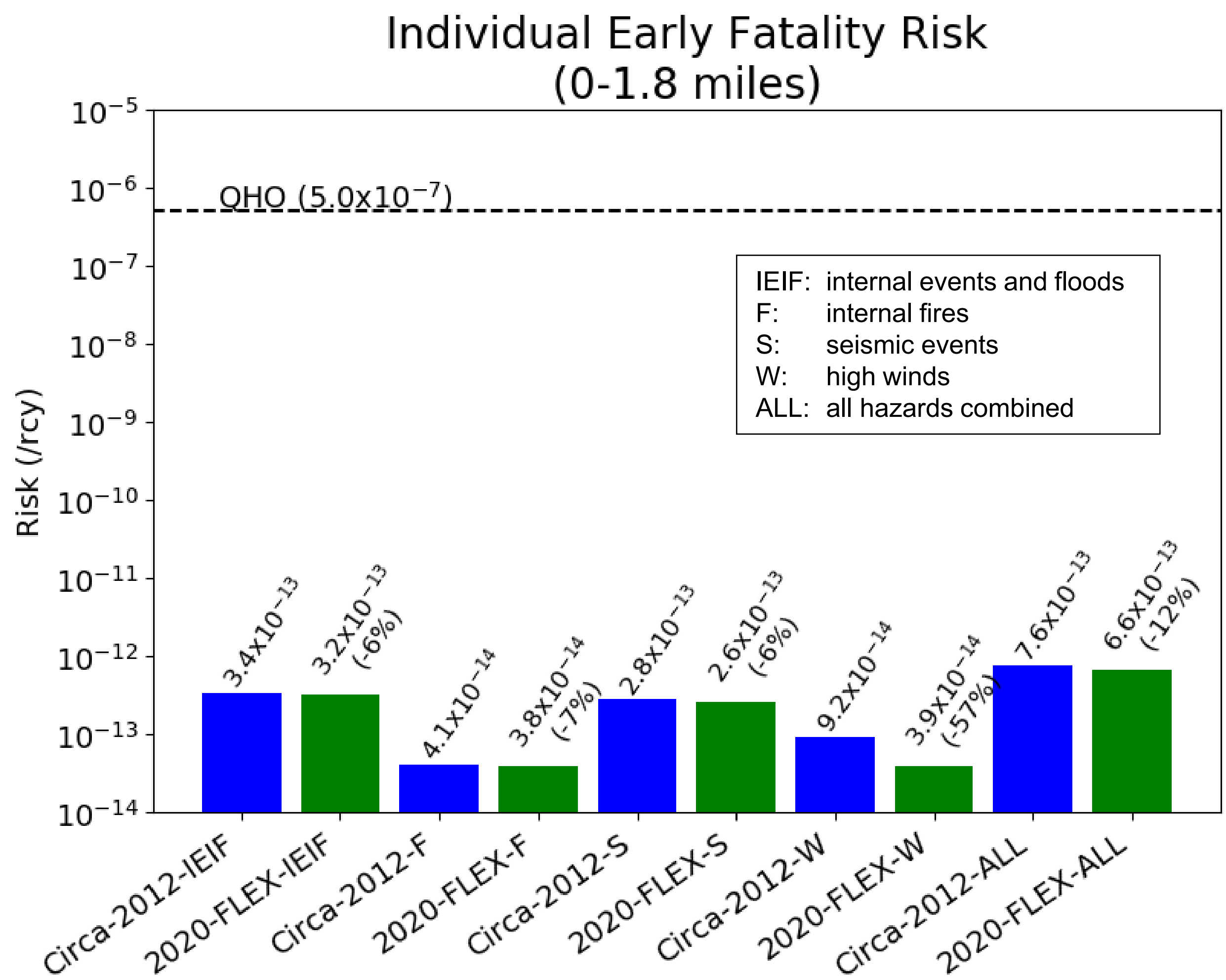
Circa-2012 Case

Level 2 PRA Surrogate Risk Metric	Time at which airborne radiological releases are terminated		
	7 days after event initiation	SAMG entry + 60 hours	SAMG entry + 36 hours
LERF	1.9E-06/rcy	1.9E-06/rcy	1.9E-06/rcy
LRF	**1.1E-04/rcy**	**3.5E-05/rcy**	3.5E-05/rcy
CCFP	0.680	0.620	**0.235**

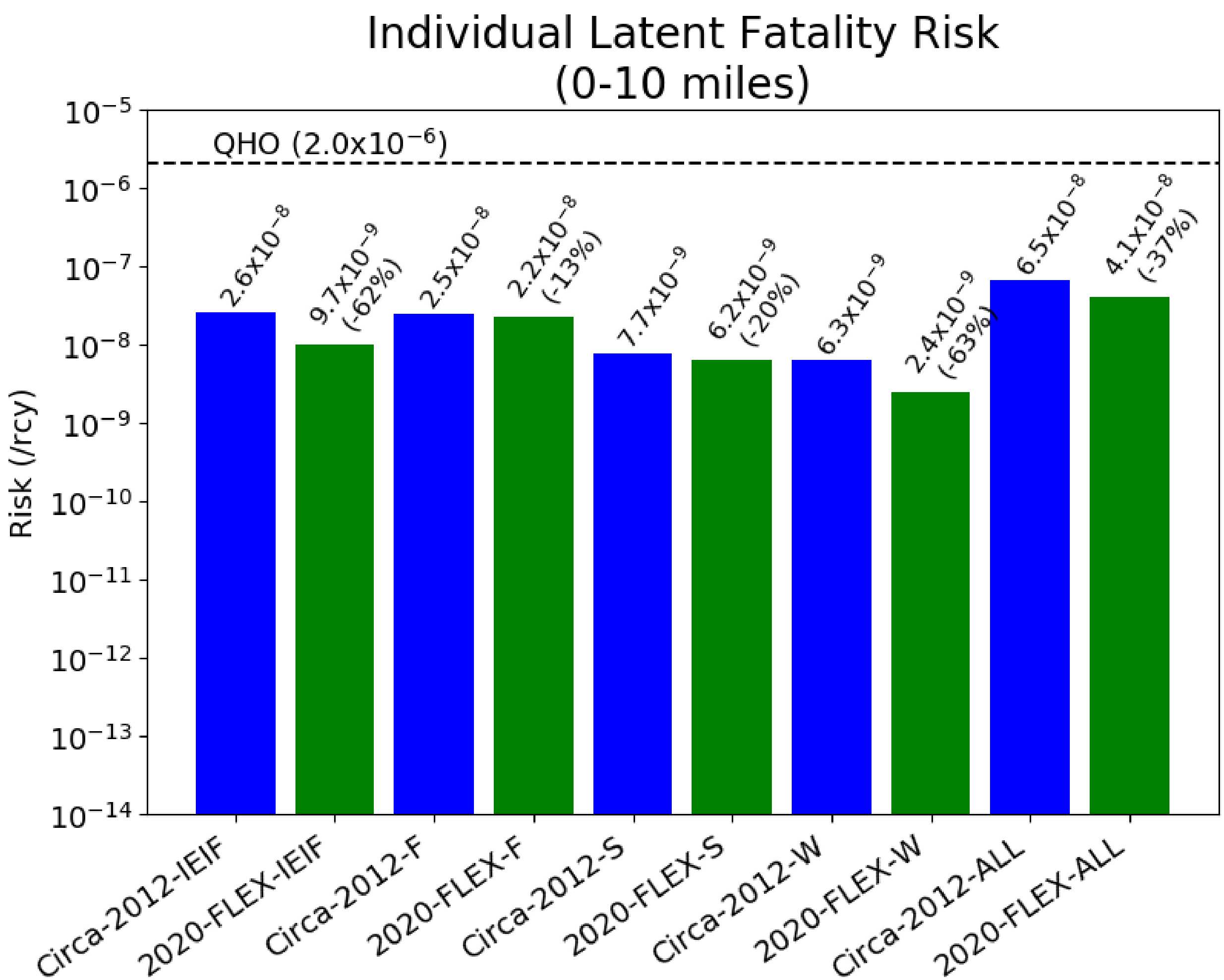
2020-FLEX Case

Level 2 PRA Surrogate Risk Metric	Time at which airborne radiological releases are terminated		
	7 days after event initiation	SAMG entry + 60 hours	SAMG entry + 36 hours
LERF	1.3E-06/rcy	1.3E-06/rcy	1.3E-06/rcy
LRF	**6.7E-05/rcy**	**2.6E-05/rcy**	2.6E-05/rcy
CCFP	0.764	0.679	**0.309**

Level 3 PRA Results (1 of 3)

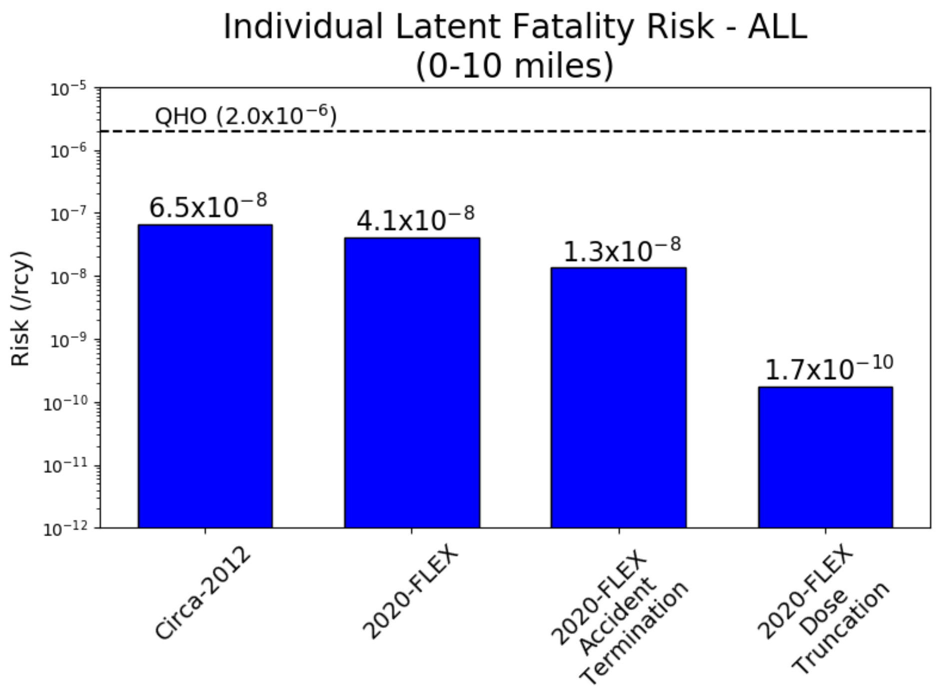


Level 3 PRA Results (2 of 3)



IEIF:	internal events and floods
F:	internal fires
S:	seismic events
W:	high winds
ALL:	all hazards combined

Level 3 PRA Results (3 of 3)



- Accident truncation – airborne radiological release termination time reduced from 7 days after accident initiation to 36 hours after SAMG entry
- Dose truncation – changed from linear no-threshold (LNT) to model based on Health Physics Society position paper, “Radiation Risk in Perspective: Position Statement of the Health Physics Society” (PS010-2), 2010

Additional Reactor At-Power PRA Preliminary Insights (1 of 2)

- Significant risk contributors to offsite public risk metrics related to early health effects:
  - Failures of RHR system components leading to ISLOCA (primarily for internal events)
  - Random or hazard-induced failures and operator errors leading to SBO that progresses to core damage and TI-SGTR given high-dry-low conditions

Additional Reactor At-Power PRA Preliminary Insights (2 of 2)

- Significant risk contributors to offsite public risk metrics other than those related to early health effects:
  - Events related to combustion (detonations or deflagrations) within containment
  - Failure of manual extension of TDAFW during SBO
  - Random or hazard-induced failures and operator errors leading to SBO
  - Other operator errors from both the Level 1 and Level 2 PRA models

Acronyms and Definitions (1 of 2)

ATWS	anticipated transient without scram
CCDF	complementary cumulative distribution function
CCFP	conditional containment failure probability
CDF	core damage frequency
EDMG	extensive damage mitigation guideline
EOP	emergency operating procedure
HRA	human reliability analysis
ISLOCA	interfacing systems loss-of-coolant accident
L3PRA	Level 3 PRA (project)
LERF	large early release frequency
LNT	linear no-threshold
LPSD	low power and shutdown
LRF	large release frequency
MACCS	MELCOR Accident Consequence Code System
PI-SGTR	pressure-induced steam generator tube rupture
PRA	probabilistic risk assessment
QHO	quantitative health objective
RHR	residual heat removal
RCY	reactor-critical-year

Acronyms and Definitions (2 of 2)

SAMG	severe accident management guideline
SBO	station blackout
SFP	spent fuel pool
SGTR	steam generator tube rupture
TDAFW	turbine-driven auxiliary feedwater
TI-SGTR	temperature-induced steam generator tube rupture