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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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FUELS, MATERIALS, & STRUCTURES SUBCOMMITTEE

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THURSDAY

NOVEMBER 21, 2024

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The Subcommittee met via Videoconference, at 1:00 p.m. EST, Ron Ballinger, Chairman, presiding.

SUBCOMMITTEE MEMBERS:

RONALD G. BALLINGER, Chairman

VICKI M. BIER, Member

VESNA B. DIMITRIJEVIC, Member

GREGORY H. HALNON, Member

CRAIG D. HARRINGTON, Member

WALTER L. KIRCHNER, Member

ROBERT P. MARTIN, Member

SCOTT P. PALMTAG, Member

DAVID A. PETTI, Member

THOMAS E. ROBERTS, Member

MATTHEW W. SUNSERI, Member

ACRS CONSULTANTS:

DENNIS BLEY

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

ALSO PRESENT:

ANGIE BUFORD, NRR

STEPHEN CUMBLIDGE, NRR

DAVID DIJAMCO, NRR

ROBERT GRIZZI, EPRI

DAVID RUDLAND, NRR

DAN WIDREVITZ, NRR

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

(1:00 p.m.)

CHAIR BALLINGER: Good afternoon again. The meeting will now come to order.

This is a meeting of the Fuels Materials & Structures Subcommittee, the Advisory Committee on Reactor Safeguards.

I'm Ron Ballinger, Chair of today's subcommittee meeting. ACRS members in attendance are Craig Harrington, Tom Roberts, myself, Greg Halnon, Vicki Bier, Bob Martin, and our consultants, Steve Schultz and Dennis Bley, are here in person.

Virtually, I believe we have Matt Sunseri, Vesna Dimitrijevic, Walt Kirchner, Dave Petti we've checked on, Scott Palmtag, and if I've missed anybody, please let me know. But I think we've got everybody.

Chris Brown of the ACRS Staff is the designated federal officer for this meeting. One conflict of interest has been identified, and that is Craig Harrington, who will recuse himself from participating in deliberations, in providing input recommendations specifically associated with the EPRI work that's presented.

We have a quorum, of course. During today's meeting, the subcommittee will receive an information briefing from staff and EPRI on ASME code relaxation efforts. In particular, background and the use of probabilistic fracture mechanics.

Ongoing efforts to relax ASME inspections, performance monitoring, and the staff's guidance under development, will be discussed.

In-service inspections (ISIs) are systematic examinations of nuclear power plant systems, structures and components, to assist their condition and determine if they are safe for continued operation. The ASME Boiler and Pressure Vessel Code provides rules for ISI, Section 11, including out-of-design systems for inspections and repair, and how to establish inspection periods and levels.

There's been an increase in ISI-related submittals that are explicitly or implicitly risk-informed. Many of these submittals contain novel applications of probabilistic modeling, or other risk-based arguments that could be used to support subsequent license renewal. For this reason, the subcommittee requested the briefing.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act, or FACA. The NRC implements FACA in accordance with its regulations.

For these regulations, as the committee's bylaws, the ACRS speaks only to its published letter reports. All member comments should be regarded as only the individual opinion of that member, not a committee position.

All relevant information related to ACRS activities, such as letters, rules, or meeting participation, the transcripts are located on the NRC public website and can be easily found by typing about us ACRS in the search field on NRC's home page.

The ACRS, consistent with the Agency's value of public transparency in regulation of nuclear facilities, provides opportunity for public input comment during our proceedings.

We have received no written statements or requests to make an oral statement from the public. We have also set aside time at the end of the meeting for public comments.

Subcommittee will gather information, analyze relevant issues and facts, and formulate the pros, conclusions and recommendations, as appropriate for deliberation by the Board.

A transcript of the meeting is being kept and will be posted on our website.

When addressing the subcommittee, the

participants should first identify themselves, and speak with sufficient clarity and volume so that they may be readily heard.

If you are not speaking, please mute your computer on Teams, or by pressing star-six if you're on the phone.

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For anyone in the room, please put all of your electronic devices in silent mode and mute your laptop microphone and speakers. In addition, please keep sidebar discussions in the room to a minimum, since facility microphones are live.

For the presenters, your table microphones are unidirectional -- extremely unidirectional -- and you'll need to speak into the front of the microphone to be heard.

Finally, if you have feedback for the ACRS about today's meeting, we encourage you to fill out the public meeting feedback form on the NRC's website.

So, now we'll -- well let's see, what do I need to do? I need to turn this over to Member Halnon for comment.

MEMBER HALNON: Yeah, good afternoon. My name is Greg Halnon. I serve as the Vice-Chair of ACRS.

After publication of this agenda, we were contacted by some industry stakeholders, that the characterization of industry presentations should be somewhat different. Should have been noticed as the actual title, which we assume the presentation, which is Optimization of Select NDE Examination Requirements.

The agenda title is different and this occurred due to some issues with titling of public noticing and receipt of the final presentation materials.

We regret and apologize that for the confusion and would like the actual record to reflect the title of the industry representative's presentation to ensure the intent of the presentation is not potentially mischaracterized.

Our desires of the upcoming presentation stand on its own to provide further clarity in the context of the topic of discussions. And, of course, the presenters may want to further comment on this as desired.

And that's it. Thank you, Ron. Now that

the record has been corrected we can continue with the meeting.

CHAIR BALLINGER: Thank you. Okay, now we'll proceed. And Angie Buford, you want to make some introductory comments?

MS. BUFORD: Sure. Thank you so much. My name's Angie Buford. I am the branch chief of the Vessels and Internals Branch. It's one of the materials branches in the Division of New and Renewed Licenses in the NRC's Office of Nuclear Reactor Regulation.

We're very excited to be here today in order to discuss with you all some aspects of risk-informed decision-making that the NRC as a whole, we're looking to be smarter about using operating experience, and also our regulations and where it made sense from a safety perspective, to look into ways to optimize and ensuring continued safe operation, whilst keeping in mind practices and good operating experience that we've seen.

And so, here today we've got a few presentations, led by our senior-level advisor, Dave Rudland, to talk to you about how we're using probabilistic fraction mechanics, and also looking at ways to pull -- we'll say, not relax but optimize our requirements for using the ASME code for their pressure vessel code and ISI requirements.

So, with that, I think I will turn it over to Dave Rudland to start. Awesome. Thank you, Dave.

DR. RUDLAND: Thanks, Angie. Yeah, my name is Dave Rudland and I am a senior technical advisor for materials in the Division of New and Renewed Licenses in NRR.

And I'm going to provide some background. As Dr. Ballinger mentioned at the beginning, these changes to ASME inspection requirements have been based on the use of probabilistic fraction mechanics.

And so, I wanted to give a little bit of background about why the industry and/or the staff rely on these tools.

I'll talk a little bit about the regulatory structure around these tools, and a little bit about some of our past experience with using these tools, and maybe a little bit about some of the successes, why we've had success and why we've had challenges in using these tools to make changes to either inspections intervals, or other regulatory requirements.

So, again, I'm going to start a little bit with motivation. And I don't mean to insult everyone's intelligence. This is a little simplistic, but it's a simple graph to try and demonstrate why the staff and the industry plan to use probabilistic analyses for passive component integrity.

Earlier in life when the plants that we have operating right now were first designed, there wasn't a lot of data available on how the components degraded with time. We had some data, but not much.

We knew trends, we knew the physics. And so, we were able to develop trend curves that showed us the expected damages, a function of time.

And to that trend curve, we added an imposed margin that we thought was sufficient to cover the uncertainties that we knew at that particular time so that we could keep these components far away.

And in doing that, there were a lot of margins placed on whether it was the operating loads, the material resistance, and things like that.

However, the imposed margins at the time really didn't impact operability at all, or anything like that, because the plants were new and they were not aged at all. They were nowhere near failure. So, the conservative trends were appropriate at that time.

However, as we've moved through our time here with these operating plants, we've gotten and developed more and more data.

And in doing that, we were able to understand the trends a little better on how these passive components degrade, and the uncertainty associated with that.

We begin to ask the question, are these, or were these original margins overly burdensome, or do we need to change the margins with time as we generate more and more data?

The deterministic approaches that we put in place early in life really are not well-suited for quantifying actual risk, or actual uncertainty, for that matter. We made estimates a long time ago, but we didn't have the knowledge.

And now that we do, we can better quantify that uncertainty. And therefore, we were trying to understand integrity issues in these passive components. These probabilistic analyses then can be used to properly account for the true uncertainty that we're seeing from the history that we've had.

At the NRC, we tried to make our regulatory decisions in an integrated fashion. And that means that we don't just look at one aspect of anything when we are trying to make a decision.

Especially since the early '90s, the

Agency is moving towards more of a risk-informed process in terms of how they think. Not just about risk to the plant, but risks in general.

How can we use risk insights to help us make decisions? And how do we do that for passive component integrity?

The figure I show here comes from our regulatory guide 1.174, which is formal process that's in place for making design basis changes based on risk-informed decision-making. And it leverages the PRA -- not extensively -- in helping to make that decision.

However, the principles and the ideas behind that integrated thinking, can extend far beyond the use of PRA.

Any time we're making decisions where we're using probabilistic tools or computer tools that make approximations, we want to be able to leverage these other things, like monitoring and safety margins, and defense in-depth in origination, well-informed regulatory decisions.

And in PFM, we can do that with PFM also. It really brings together and focuses the information from the risk triplet. What can happen? How often does something happen, and what are the consequences?

PFM, for example, can be used to estimate probability of leakage or rupture of a pressure boundary component. And you can answer and ask all three of those questions, with that outcome in mind.

So, the outcome of any type of the type of analysis that uses probabilities that look at the changes in the failure frequencies, is inherently a risk insight.

And so, we recognize at the NRC that this PFM is a leading technique for managing risk-informed management of long-term passive components.

MEMBER DIMITRIJEVIC: Hi, this is Vesna Dimitrijevic. If you're calculating change in failure frequency, that's a clear PRA application. So, it's not your safety margins and defense and that.

Thus, when you're talking about failure frequency, those are the numbers just used in PRA.

DR. RUDLAND: That's very true. And as I'll mention in a second, in a lot of cases it impacts the initiating event frequencies in a PRA. I'll touch on that in a second.

MEMBER DIMITRIJEVIC: Okay. All right.

DR. RUDLAND: And I think that second is right about now.

So, when we talk about PFM and its use in this integrated decision-making process, we have to remember that these PFM analyses that are calculating failure frequencies, are just one part of this risk-informed integrated decision-making process.

And like mentioned here on the phone, we still need to be able to incorporate those other ideas, to make sure that the analyses and the results that we get from those analyses are being consistent all the time.

And to the point I was just trying to make, I'll make an example here, which is shown on the left part of this slide, if we're going to take a relaxation to inspection, design, maintenance requirements, it doesn't even need to be relaxation. It can be any kind of change to those requirements.

We may want to do a PFM, or similar type of analysis that may impact the initiating frequencies in our plant PRAs.

If the results from those analyses are very, very small -- so, if you have a very, very small change in failure frequency, such that, for instance, it is below the initiating event frequency that's currently in the PRA, I think we can say that it won't probably impact the impacts to the plant. The Delta CDF or the Delta LERF would be very small without having to revisit the PRA.

In an event where that frequency might be larger, then yes, the LOCA frequency or other frequency, initiating frequencies, would need to be updated, and a PRA would need to be run.

And in that particular case a process, like in Reg. Guide 1.174, may be needed in order to make that submittal.

But in the other case, it may not if we're not really leveraging the PRA to estimate the change in CDF.

I wanted to take a step to look in the past at how many of these different kinds of codes have been developed over the years.

We have been working and developing, both at the NRC and in the industry, on these probabilistic fracture mechanics code since the 1980s.

This colorful plot shows in red those codes that are NRC-developed, in blue those that are industry-developed, kind of the mixed colors where we've jointly worked together to develop these codes, and the yellow kind of curve is our international codes that have been developed.

And what you see is that there was a lot of codes up front, a lot of codes that did a lot of very similar things.

Our philosophy was to try to develop codes that may be more generically used for a particular system.

For instance, piping systems. Maybe we can use xLPR for all piping issues. And maybe FAVPRO can be used for all vessel issues.

But what we see coming out of the industry right now, is the turn to more problem-specific code generations.

So, we had these large codes that we've developed in a strict QA fashion. And then, there are plant-specific, or problem-specific, codes being developed also.

So, we have to be able to take a look at both these large codes, as well as these smaller problem-specific code.

And what we're talking about today, both Dave Dijamco and Dan and Bob will be talking about, is this promise code, which was a probabilistic fracture mechanics code, looking at the failure of steam generator and pressurizer shell wells.

Touching on the licensing review process and the regulatory processes for some of this, I jimmied up this illustration to kind of give a feel for where we sit in terms of how these processes are defined or not.

On the vertical access here, is kind of the acceptability level for the risk insights, or PRA, and on the horizontal axis is the reliance on the detailed licensing risk information.

When you're all the way over on the right-hand side of this chart, you're in a very defined processes. The Reg. Guide 1.174 I show up on top, is one of these well-defined processes where quantitative risk information is needed in order to make a regulatory decision.

On the far left of this plot are relief requests where a lot of our intent is to deterministically argue in the applications, where there is no risk insights that are mentioned. That process is also well-defined.

Things that we've been using with PFM kind of fall in the middle there. The risk insights that are submitted outside of the formal licensing basis process.

So, how do we do that? And so, the staff has been working on developing guidance to be able to help both the licensees and the staff process through these types of applications. And we'll be talking about that later on, what the staff is doing.

MEMBER HALNON: Vesna spoke up. Jump in, Vesna.

MEMBER DIMITRIJEVIC: Yeah, this is Vesna Dimitrijevic again. I can wait for your talk later this afternoon.

I just want to say, because you mentioned this again, that Reg. Guide 1.174 is not necessarily applicable here, because that's for the changes in the plan. And this is not a change in plan, it's change in method you're using to calculate something. So, I think maybe now the Reg. Guide 1.174 would be applicable for this application.

The second thing is also that, I mean, in sum, you didn't really measure the right application where I think that could be most interesting. And this is an internal flubbing, where there is not really good data for the frequency.

But the thing is, in the risk-informed in-service inspection, the two metals -- EPRI and Westinghouse, and one is already using Westinghouse -- the fracture mechanics results in that.

So, also the 10 C.F.R., there is a lot of questions about those applications. So, I'm actually looking forward to your presentation later on. Okay?

DR. RUDLAND: Yeah, thanks. Yeah, a lot of this, especially the risk-informed in-service inspection, used these tools in developing that particular basis also. So, it's very tied in.

MEMBER DIMITRIJEVIC: Are we using the Westinghouse metal, which most of the plants today using EPRI metal, which doesn't apply fracture mechanics?

DR. RUDLAND: Yes, yes. In this slide, I kind of wanted to show the timeline of how the applications have come in using probabilistic fracture mechanics.

And it ranges all the way from the 1990s to today and had a wide variety of different applications.

We have regulations, like the PTS regulations, how it's sort of yellow, guidance, which art the green ones, 1.178 is the risk-informed in-service inspection for piping Reg. Guide, the blue are actually applications from the licensee where they've used PFM, and the light blue are actually OE that the staff analyzed using our LIC-504 process, which is similar to the information that's in Reg. Guide 1.174.

And it's not stopping with these that are shown here. We have future uses of them right now.

There's an ongoing rulemaking for increased enrichment high-burnup fuel, where PFM is being used.

Dan, we'll talk about RIMA later. And plus, there's a lot of opportunity for other inspection changes due to results from probabilistic fracture mechanics.

So, the technology has matured over the years, and as you can see, more and more applications occur later as that technology has matured.

The oval that's shown on that figure is what we're going to be talking about later on this afternoon. It is the steam generator and pressurizer inspection relief request.

And we've had good successes, for the most part. And that typically happens when the computer codes that are used have well-technically-justified bases and a very good verification and validation programs.

They have followed the process. And again, I'm not talking about the application using 1.174. I'm talking about this risk-informed process that I talked about earlier was followed. Performance monitoring was sufficient in its use.

Sometimes, and in many cases, they leveraged both deterministic and probabilistic analyses in the calculations, and I've done sensitivity studies to demonstrate impacts on important variables.

With successes, we've also had some challenges. And because of these challenges, a lot of times guidance has been developed, which, again, we'll talk about a little bit later.

But many of the challenges have been because there hasn't been very good, or incomplete, uncertainty characterization.

The code has been closed to the staff and they have not been able to review either the basis or the code itself.

They don't have well-documented QA or verification and validation. Sometimes, some of these criteria that we've talked about earlier in this integrated decision-making were overlooked.

Also, a lot of issues with acceptance criteria. Because there's no specific rules about what is an acceptable change to a failure frequency, there's been a lot of discussion about that.

And so, the guidance that we have developed and is being developed is meant to try to tackle all of the challenges that we have seen to date.

So, I just wanted to give a quick summary of where we were and how we see PFM, and how it's being used. And we recognize it really is a leading technique right now for managing the management of long-term past components.

And it can be a tool. It can always be a useful tool when optimizing inspections, as long as we are able to leverage this integrated decision-making in making those decisions.

And as we'll hear, we continue to develop guidance to try to help both the staff and the licensees with submissions that use probabilistic fracture mechanics.

MEMBER MARTIN: I'll jump in with a comment, because I can't help myself.

This is Bob Martin. So, maybe it's inappropriate but I'm bringing insights from this morning. We of course had the fuel subcommittee meeting, talked about materials reliability program.

And at the end Ron put me on the spot. I acknowledged my ignorance in so many ways there. But it was one thing maybe that I hear here that made me fill in the gap for me from that earlier meeting.

The question there was how experiential that world is. Right? Inspections, a lot of visual tactile, and the philosophical statement here.

But purpose is often found in the balance of the rational and the experience. And I look at this as providing some balance. It can sometimes provide some insights to maybe your comment earlier about the unknown unknowns.

Combination is much more powerful than, of course, the experience alone. And of course, we like to lean more on experience. I absolutely believe that. But I really like this because it provides, hopefully, cooperative insights to what we see.

And then, we talked about letters and stuff. But you noted at the end of the last meeting that there's a lot of overlap between morning and afternoon.

But in looking at this, there's a synergy of topics that might be worth writing about, as a letter, or maybe at least further meetings or something. And I really like what I'm hearing.

DR. RUDLAND: I'm going to point back to my simplistic figure here. The work that we talked about in the analysis does a good job of utilizing this kind of data and making predictions from it.

But anything above the last data point, we don't really know if we know what we're extrapolating in time to occur, which is why we have this integrated process.

To continue doing that monitoring, to make sure that that curve doesn't change dramatically with time.

And so, I think, to your point there, I think that's what's really important and what really pulls it all together, is that we have really good data, we've got really good models. But we still need to continue to look to make sure that we don't miss something, or something doesn't change.

MEMBER MARTIN: Sure. And accident analysis relied mostly on computer codes. But we back it up with all the tested. When it comes to aging, inspections and such, we lead with the experience, but we need to maybe, as an analogy, back it up with analysis.

MEMBER ROBERTS: I have a different question, related also to this morning, to some degree. Could we go back to the very last slide? The summary?

The second bullet talks about PFM used with or without PRA. I think about what that means in terms of being risk-informed, and let me try something on you to see if I'm capturing what you're saying, is if you have something that's moderated in the PRA, like pipe break frequency, then you can pretty directly tweak the PRA based on whatever you're changing in your analysis methods to change your margins whatever, to changes of a frequency curve, if you find that you've screened out in the PRA, like reactor vessel rupture, or like what we talked about this morning, core valve failure, then what you're really doing is saying, do I still have enough safety margin to support the screen decision, which is still basically risk-informed, because it's supporting a decision you've already made that the risk analysis updated to conclude the failure of that system, the component, but it's still a deterministic analysis, because you're judging based solely on safety margin, and the results of the risk analysis. Is that right?

(Simultaneous speaking.)

DR. RUDLAND: Yeah. Again, if you define deterministic analysis as a PRA, then yeah, I tend to agree. The issue is that if you use these probabilistic tools and you come up with a failure frequency that maybe challenges the screening that you did, or something like that, then you need to take a closer look at how that may impact your PRA if it's screened, right?

But I think these risk insights, while they're not PRA, can still add a lot to, maybe not the core risk, but other risks that may occur in plant operations.

MEMBER ROBERTS: That makes sense to me. You're looking basically for a cliff edge effect that says you screened it because the consequence could be more than you're willing to accept.

DR. RUDLAND: That's right.

MEMBER ROBERTS: And as we move to the analysis, but now you've gotten to where you're closer to why you screened it, to maybe you can't support that decision, in which case it could be a completely different analysis. You need to be able to --

(Simultaneous speaking.)

DR. RUDLAND: And we can look at it at a much higher level, and if there are analyses that are done that challenge tech specs, or something like that, you can use those risk insights to decide whether a tech spec needs to be changed or modified, or something, in that aspect.

MEMBER ROBERTS: Okay, thank you.

DR. RUDLAND: Mm-hmm.

MEMBER DIMITRIJEVIC: I would like to add something here, just to clear some things. The fracture mechanic analysis is not used in PRA either for the pressure vessel failure, or for the pipe failures for LOCA frequencies.

We're all familiar that the LOCA frequencies, we use expert opinions. And for pressure vessel failure, there was a screening value of ten to minus-seven, because it was smaller than most of the PRA results and it was screened out, or was just left as advanced scenario.

The fracture mechanic results are sometimes used in internal flubbing analysis to determine the initiating event frequencies.

Fracture mechanic results have a lot of challenges. And that's why I was hoping we will learn a lot about, because there is a lot of exceptions which have to be made. For example, the number of the flows that -- about the challenges propagation, blah, blah, blah, how the inspection affects that.

So, they come with a lot of uncertainties. And that's why they're not directly used. Also, the piping never shows in the fault trees. The piping only comes indirectly through the initiating event frequencies.

So, because one of those slides was about how these fracture mechanic results have improved over time, even if they improve, the time, the practicality of the use can be always the question.

And we definitely, it would be interesting to see some reasonable number for the pressure vessel -- the vessel failures. So, this is just my addition from the PRA perspectives, that they are actually not a part of the PRA out of the internal flooding.

And if you say that we want to use the fracture mechanics to calculate LOCA frequencies, just you mention what would that imply? The counting the number of the valves, the different challenges and inspections, and it will be very complex process.

DR. RUDLAND: Yeah, I totally agree it is very complex. But the staff have used, in analyzing emergent operational experience, when we've had issues with piping, we've taken these types of tools and estimated changes in LOCA frequencies, based on degradation, or whatever the case happens to be, and then gone back and you run the PRAs with that change and initiating frequencies, to see what the impacts of that operational experience a degradation would have been to the plant risk.

So, while it's not typically used, the staff have leveraged that in several operational experience cases.

MR. WIDREVITZ: I think I would like to expand on that. Did we all recognize that PRA is not a physics, first principles, digital twin of the plant right now? We make some assumptions, right, the only thing more complicated than the PRA is the plant itself.

So, PFM is taking the problem from the direction of, you have physical component with the geometry with a stress state, you take the knowledge that you know and you see what you can understand about that component under certain conditions, you can run sensitivity analyses, you can run sensitivity studies on that as well, and you can say essentially, one of the things that PRA does is -- and there's quite a big report about it -- is that's the main LOCA frequencies. Right?

And that draws in a lot of information. And for a lot of the work that we do, when we want to look at a delta in practice as being proposed, we want to say that it received from PFM -- for example, does this change our understanding of what we've assumed in PRA for these sorts of components that are not necessarily directly modeled in a PRA? In that pile of assumptions, you need to get to where that model actually gets.

And so, PFM is something that's been used fairly often quite successfully. We've had a lot of good validation and verification on a number of subjects. It's the tool we actually have, as far as the physical component and things like the fracture frequencies.

And because we're often using it to verify that we're not violating assumption PRA, as long as we meet that level of evidence, we're in a good place, especially with the sensitivity studies and sensitivity analyses, and tells us what we need to know so we don't need to ask a bigger question to understand what's in front of us.

CHAIR BALLINGER: Dave?

MEMBER PETTI: Yeah, you may have just answered my question. Go back to the plot with the fake data that got tuned up front.

CHAIR BALLINGER: Fake data.

MEMBER PETTI: There you go. Yep. That one's good. That one's good. Yeah.

So, I want to get a sense, because I know you've talked to us about it -- we get hit with so many things, my mind can't hold all of it together -- which is, how accurate are the predictions of events that have already happened? You listed a bunch of events.

What's a sense of assurity with probabilistic fracture mechanics A and B. I assume we always take, like, the upper 95 percent confidence in any regulatory assessment.

DR. RUDLAND: Yeah. So, a lot of these codes have been -- there's been a lot of time spent in validating the codes. And especially for a lot of the failures in the power plants, there hasn't been many.

So, there's not a lot of data of pipe ruptures, or reactor vessel failures, to validate the final probabilities. But what we do is we look at the behaviors, the fracture mechanics behaviors, and we closely validate those against experiments at the kind of lower level pace.

And then we look at the reasonableness of the results compared to the operational experience that has occurred -- leakage, and things like that.

So, overall, I think, especially since we take into account that uncertainty band in the calculations, that I feel pretty confident in the results.

MEMBER PETTI: Okay, thanks. That helps. Because we hear about this in thermal hydraulic space all the time in validating those codes. This is just kind of a new area. So, that helps. Thanks.

DR. RUDLAND: Yeah. And I'm sorry, I don't know the member's name, the woman that talked, I don't know her name.

CHAIR BALLINGER: Vesna.

DR. RUDLAND: Vesna. To your point about understanding the codes and stuff like that, I mean, we briefed ACRS -- gosh, maybe it's been two years now -- on Regulatory Guide 1.245 and the basis for that.

That Reg. Guide is on probabilistic fracture mechanics and how licensees should use the results and how they should present the results to the NRC in any application.

So, if we need to revisit that for the committee, I would be happy to do that.

MEMBER DIMITRIJEVIC: Okay. I will refresh my memories on that. I mean, I'm open-minded about those, because I just say that today they don't play the big role in the PRS.

DR. RUDLAND: I should also say that now that you have a member on the ACRS also, who is an expert on this stuff, so you can also ask him. Okay, there's nothing --

CHAIR BALLINGER: He can't say anything.

DR. RUDLAND: I know.

(Simultaneous speaking.)

DR. RUDLAND: Okay, if there's no other questions, we'll move on. One second.

MR. GRIZZI: Thank you. My name is Robert Grizzi. I'm with EPRI. I'm a program manager in the NDE program. I was here last year. I think in early 2023 we came and talked to the ACRS on overall program review.

And this project was actually one of the items I covered, but only in about two slides. So, today we're going to go a lot more in-depth about the project, the background of it, and then talk about how the industry strategy is evolving a little bit based on the implementation and the project results. And so, this is an optimization to select NDE examination requirements. Next slide?

So, the premise or impetus behind this project really is borne out of industry desires. And like with any good problem, you want to create a problem statement. And this is the essence of the project.

And the essence of the impetus behind it is that there was a lot of exams being conducted that were perceived to have low value because they had fewer or no relevant indications found during these prescribed intervals that are assigned by ASME requirements for these inspections.

And then when you look at where did all this come from, well, when were these intervals, or when were these codes developed? And that was early on in the operational periods of the reactor fleet.

And who established them? Well, they were done, codes and standards, in a different participating organization at the time -- industries, the regulator, as well as the codes and standards.

And then how were these intervals established? Well, when you look at them, at the time that these plants all came into operation, we didn't have a lot of operational experience. We didn't have a lot of inspection results, because they were new.

So, these happened 40 years ago and 50 years ago, and it was really based on a lot of engineering judgment and a consensus platform. Next slide?

MEMBER HALNON: This is Greg Halnon. Is there no value, or low value, in inspection that shows that the design was adequate and that there's no problem with the materials?

MR. GRIZZI: Well, there's certainly value in those inspections. It's easy to show that there's you are continuing to run without the degradation.

So, there's a statement that says there's no relevant indications it was low value. I mean, I get that from the failure side, but to the positive side, there is some confidence in some value trending, extracted from having materials not be sure in failure mode.

MEMBER HALNON: And the challenge -- and you'll see it shortly -- is, is the frequency of the inspection optimized based on both the operating experience, inspection results, and applying some new probabilistic tools, and looking at just the overall holistic picture? And how frequent do these need to be inspected to still maintain a level of reliability and quality that were originally assumed when the intervals were established up front?

So, the challenge is to balance those two so you're not putting too much credence in either one.

MR. GRIZZI: Right.

MEMBER HALNON: Maybe biasing towards making sure your failures are not causing a problem.

MR. GRIZZI: Right. So, yeah, the balance of your frequency versus your failure, where is that balance? And that's basically what we're aiming the entire thrust of this project.

MEMBER HALNON: Okay, thanks.

MR. GRIZZI: Yep. So, and just to show a little bit about how the industry went about this, it wasn't willy-nilly when it came to establishing the components and the inspection results behind it.

They put together a level of metrics. And this dates back to 2017. There were surveys put out by this focus group of industry members that was led by EPRI, but really, the focus group was constituted by utility members.

And again, they put together a little metrics for the survey, to be able to collect that data from the entire U.S. fleet.

And it exists in this EPRI report that was put out in 2017 or '18, the results of those surveys. And then that did parlay into the work that was then followed on with building technical bases behind these different components that we're getting ready to talk about. Next slide?

So, through those surveys and through those metrics, you can see here this was the scope of the entire project. It encompassed components for both PWRs and BWRs.

The first one there is an ASME B-N-1 exam. It's a visual exam with a general area in constitution in accessible areas within a reactor vessel. That actually transformed into a Code Case N-885, which has been accepted, approved by ASME code and applied, I think endorsed by the NRC as well. I don't know if they reviewed that.

PARTICIPANT: I'm not sure.

MR. GRIZZI: -- recent rulemaking or not, but that is an applicable code case. Those reactor vessel studs, there's some non-reactor vessel pressure-retaining bolting.

And before that, you see highlighted there in the magenta color, the ones that we're really going to be focusing on today, and they encompass both the pressurizer and all the components of the steam generators.

So then last, when there was the BWR heat exchanger, that was also one of the items that was identified as having a lot of infection being performed, but really no indication of relevance supporting potentially the need to inspect that frequency. Next slide?

So, from an objective standpoint of the project, we're looking at optimizing these examination requirements. And how do we go about doing that?

When we look at the historical operating experience of the plants, we take into consideration the inspection results in the data that's been produced, we look at the fundamental engineering methods that need to be applied to be able to support the analysis, which comes with some of the modern day analysis tools that we've been talking about.

In particular, PSM, and that was one of the things that was developed for this project, is the promise code, which is a vendor-developed code that the U.S. NRC did audit.

And the audit is in the ML, or in the ADAMS, so that is something that can be looked at if it was of interest. But it was a successful audit and the PFM platform was used for subsequent submittals that we'll talk about in a little bit.

But then, in the objective, we wanted to make sure that we did all of this without compromising the safe and reliable operation of the nuclear facilities. So, that was the paramount of this objective when we put together this project. The next slide?

So, this is a little bit of data from -- am I coming through on this slide? Seems like I am.

PARTICIPANT: Yeah.

MR. GRIZZI: Okay. This is the data

through 2019 when the surveys were conducted. And this is just a good sort of snapshot of what the industry has done up through 2019.

And we look at steam generators. So, there are, depending on the plants we're looking at, you have two, three, or four steam generators at a plant, and in those steam generators there are multiple items of inspection.

And if you look at the number there, you can see that it's 2,201 examinations that were performed through 2019, all the steam generators in U.S. operating fleet.

In that bevy of inspections, there were only three indications reported. Without reading it all, the three indications, or disposition, is either fabrication, or non-relevant in-service indications.

So, basically, what is that saying? And I can speak with confidence for the last five years, the inspections that don't show up on this number, we still have not had any indications that have been reported in steam generator inspections for the components, the items that we're talking about today.

So, technically, there's no indications that have been uncovered through inspections, for the life and the operating units in the U.S. fleet. And for that matter, without pre-high-level confidence, without serving the global fleet, we can speak pretty confidently that there had been none found in the global fleet either. We're pretty sure that we would have heard about it as well, if that were the case.

And then in the pressurizers, the same situation. There's less inspections, or examinations, that were performed on pressurizers. That's because every plant only has one pressurizer.

In that allotment of inspections or examinations, there were four indications, and they were all dispositioned through flaw evaluation.

You can see that at the bottom bullet says that their dispositioned that the indications had follow-on inspections that did not show up any growth or change in the flop type.

So, essentially, we're in the same situation of pressurizers as well.

And it really does speak to the design and the robustness of these components in the welding and the different aspects of these components, in terms of their robust design.

And originally, these components and the licenses were based on 40 years. But I think we've learned during the course of these 40 years or so, or

50 years since plants have been operating, that they were very much a robust design that has a lot of life and a lot of integrity left in these components.

MEMBER HALNON: So, when we're having to deal with, I know that the VC Summer crack in the hot leg next to the nozzle, there was nothing unique about the root cause. It could have happened in any of the large bore pipe.

How do you handle that in this we're talking about, and we've had all these examinations and no failures, when we clearly had one?

MR. GRIZZI: Well, that was in a December round weld. And to be a little more explicit, the components here are, I guess, more discrete. The components that we're talking about here are either a nozzle-to-vessel weld -- so, averted weld, or where the nozzle set in the vessel -- or we're talking about a vessel weld, or we're talking about an inspection of an inside radius of the nozzle, so the area of the radius and nozzle in the nozzle boss.

So, those are the three primary inspection items that we're talking about, and nothing outward of that. So, when that dissimilar metal ties in -- we've had many indications in dissimilar metal welds over the years and those different hot legs and cold legs.

MEMBER HALNON: So, those won't be in the population.

MR. GRIZZI: Yes, they are not in the population.

MEMBER HALNON: Thanks.

MR. GRIZZI: Next slide? And this is just, like, a brief outline. Every one of the technical bases that have been put together to support these different examination items contain these items.

So, there's the introduction, obviously, and then a review of the previously related work. So, other industry work that was supported by PFM that looked at optimizing examinations, like reactor pressure vessels, or reactor pressure vessel heads. Right?

They've gone through similar efforts to take into account the robust designs and the lack of indications, and there's been optimization of those inspections as well. So, that's discussed in these bodies of work.

And then, as I mentioned before, we did a review of the inspection history of all these plants, and then surveyed the components, to make sure we selected the right components to bound, as best we can, the entire fleet.

So, for instance, if there were maybe -- I don't know, if there were four different nozzle designs for steam generators, can we analyze one or two, and that was found in the rest of the four or five other designs that are out there, initially with that portion of the reports about?

So, it looks at bounding conditions. And it does take into account the design criteria that's in the ASME code. So, all of the reactors in the design rung, Section 3, where there are parameters in terms of the design. So, we made sure we bonded those in the analysis work that was done.

And then there's discussion on material properties and operating loads and transience for all the different plants, and how those particularly interact with the analysis that takes place.

And then there's discussion on degradation mechanisms. And there's probably -- I don't know them all off the top of my head, but there's probably discussion a good eight, nine different degradation mechanisms that are considered. But at the end of the day, the primary driver was fatigue.

And then there's an element of each report that deals with the stress analysis. So, there's a finite element model that's built. That finite element model is being used in the probabilistic fracture mechanics.

The finite element model defines the highest stress concentration paths, and then that's used in the probabilistic analysis.

Most of these reports -- and I say most because the first one that deals with visual inspection, actually didn't use any probabilistic fracture mechanics, it used it in some level of deterministic.

But even in the cases where probabilistic fracture mechanics was used, from a belts-and-suspenders standpoint we ran deterministic fracture mechanics as well.

And then the last two items covered in the report is plant-specific applicability. So, basically, it is an outline of how the plant applies technical bases, in terms of what criteria it needs to meet to be bound by the technical bases, before they go ahead and submit a request for alternative to the NRC. And then, obviously, there's a summaries and conclusions part of each of these.

These are all publicly available reports. So, if you were so inclined to dig deeper into the analysis work that was done, or maybe you have a hard time falling asleep at night, these might be good letters to read, right? So, next slide.

So, the generalized conclusions of all these reports -- and I'll say generalized, but in the probabilistic report, the probabilistic technical bases all sort of culminated in the same conclusions.

And the reports and analysis work was all done based on 80 years of operation. So, we considered 80 years of operation in the calculations and the analysis studies that were done.

They were all acceptable by the safety margins, or safety threshold, that we set as a target, based on the standard that's typically used for these types of evaluations, and that's ten to the minus sixth, failures per year of operation.

And the results then also support, based on the optimization of these exam requirements, the results support mitigation of health and safety risks for those that are performing these examinations.

And I say that because you can optimize examinations and you can reduce the number, and still not affect the quality or reliability of the safe operation of the nuclear plant. You remove the health and safety risk by doing the work that people don't have to necessarily perform.

It also promotes ALARA for the same reasons. And one of the main things is that if you are performing a lot of work on items, or inspections on items that may not necessarily need to be inspected at the frequency that was originally determined, maybe you're not focusing on other areas that need more attention.

So, you are diluting resources, instead of focusing them on other areas that, again, need more attention. So, next slide?

And these are just the reports themselves. And this is really how they were implemented. So, from the beginning, the technical reports were established. And there was series, or there was a number of pilot plants that took each of the reports that are highlighted in magenta that we're talking about today, with the exception of one on the next page, I believe.

One of them has not been run through as a pilot plant. It is a subset of components for the steam generator, which is where auxiliary feedwater nozzle is attached directly to the actual steam generator component itself, as opposed to one of the pipelines coming off the steam generator. And that's a subset of plants.

That was something that we sort of discovered after we went through the original steam generator technical bases development. And that has not been exercised, but we do include that as all-encompassing from a steam generator standpoint, where we talk about, later, the performance monitoring aspect of this project. So, next slide.

Yeah, it looks very much the same but it is different. Again, these are all publicly available reports. So, those are the product numbers if you go to the EPRI website, and you can download those. Next slide.

So, initially, you have some implementation strategy. And the benefits, as I mentioned, there are the pilot plants that we lined up to exercise these technical bases, all submitted through the NRC request for alternative process.

In that evolution, these PFM tech bases were exercised. They were not submitted as topical reports, but they were supporting technical documents. I don't believe that the NRC recognized them or endorsed them in any way, but I think that they were reviewed on some level. I'll ask Dave, can you comment on that?

DR. RUDLAND: Yeah, the topical reports were submitted with -- and Dave DiJamco will talk about this after Bob's finished -- but the topical reports were submitted along with the alternative requests. And the reports were reviewed for the licensee's application only, and not for generic --

MR. GRIZZI: So in terms of the implementation, as I mentioned, the analysis work was done out to 80 years of operation. But in terms of the submittals for the request for alternatives, we only went out to maximum of 30 years for the optimization or for the extension of the interval. So there's a level conservatism actually built in to these submittals that we put forth or that the industry put forth that are well below the thresholds in the analysis that was done on a technical bases.

And of course, I sort of mentioned the benefits before. But at the end of the day, there's always a cost element to it. So it is something that is saving utilities, a dollar figure. And they're all independent or specific to each utility.

But at the end of the day, those dollar figures are driven by dose reduction, unnecessary work production, the mitigation of the health and safety from a -- just from a liability standpoint. So the industry is not hiding anything by that. They acknowledge there's a lot of benefits and one of them is cost. So next slide.

So with that, and as I explained that the industry went through these pilot plan applications. So there was -- for each of the tech basis that were in the list earlier on, there was eight of them. And the ones we're specifically talking about today are the probabilistic mechanic tech basis that support the steam generator and pressurizer.

So with the pilot plans, there was about three or four that went through the process. And after that, once those pilot plans showed a level of success, well, obviously there was some other plans that came about to follow on. They wanted to follow in the footsteps of the pilot plans to be able to receive some of the same level of requests for alternatives.

But with that, there was a shift in the strategy. And that's what we're about to talk about now is that the industry decided along with the conversations with the NRC that a shift in strategy is probably of mutual benefit for both the industry and the regulator. So that's what we're going to go over now.

So again, these are the technical bases that we're going to talk about, pretty much a repeat. But these are the four we're going to focus on. And again, the analysis went to 80 years.

And with that, some of the analysis was on orders of magnitude a little above -- I don't know how you want to say it. But they ceded the benchmark of 10 to the -6. So on orders of 10 to the 7, 10 to the 8, 10 to the 9 depending on the components and the weld that we're talking about for the inspections. Next slide.

So we're talking about the shift in implementation strategy. The U.S. started, as I mentioned, the applications using a pilot plan as more of a feasibility study. After that, there were, as I mentioned, follow-on plants.

There as 23 of the 61 plant sites that had followed on to the original pilot plant. So you can see that number, while it isn't a huge number, it's not even half of the operating fleet. But it's still pretty substantial number.

And that puts a burden on each of the individual plants as well as the regulator to have to do a level of assessment and evaluation for each one of these on an individual basis. So collectively the

U.S. utilities want to shift to this fleet-wide approach to be able to support more of a performance monitoring implementation strategy. And it parallels or is very close to what happened with the reactor pressure vessels in the 10 or 15, 20 years ago where they moved their inspection intervals or their frequencies from 10 years to 20 years.

And they collectively looked at how we do this as an industry. So that's pretty much the format or the parallel method that we're looking at from the industries from a performance monitoring standpoint. Today when I talk to you a little bit when I go through the examples, I'm only going to be talking about the steam general because the pressurizer is pretty much parallel to steam generators in terms of approach and methodology.

So there's not a lot of sense to talk about both of them and just realize that they do follow the same path and approach when it comes to how the performance monitoring plan is put together. Yeah, and we've been discussing this with the NRC for probably the last two and a half, three years collectively. And it's been a lot of good and enlightening discussions for both sides, I think, for the industry as well as the NRC to come to some mutual or common ground on how this works from both parties as opposed to having to go through these on an individual basis.

And I think that there's a lot of -- there's lots to be gained for the industry looking at this from a collective standpoint. So next slide. So this is some information we put together a while ago when we figured that the industry needed to really come up with do we understand what the NRC's concerns are. And I think this sort of sums it up.

From a performance monitoring standpoint, from a fleet-wide performance monitoring standpoint, there's an element that has to deal with the statistical relevancy of many data points that you actually have in a data set which is the first concern. You'll see there. It says the NRC's binomial distribution model defined a minimum number of inspections that need to be performed across the feed.

And I think later -- in a later presentation, they're going to get more in depth about that binomial distribution model. But just keep in mind that was one of the objectives of the industry is to make sure that we address that criteria. And then the second item is, do we have sufficient continuous distribution of those data points across the operating fleet?

So every reactor -- sometimes I think we get lost in the fact that all these operating reactors have different end points in their life even though the fleet started operating four years ago when you look at the slide I put together. So I think it sort of opens everybody's eyes, at least it did for mine, because we talk about these chunks of years and we talk about 10 years and we talk about 40 years of operating, 50 years of operating life. But it's really a huge cascading effect in terms of when all these different operating plants actually had that in their operating license.

So it's important to be able to have a consistent distribution across that operating life span from all the U.S. fleet. And it's a hard, fast line at 50 years. So we'll see that in a minute.

The surveys of the fleets that were conducted that we did after we started getting into the mode of doing this shift in strategy for performance monitoring, we went out and resurveyed the fleet to get all of their information on how they perform their in service inspection examinations on these 10-year intervals. So we collected the intervals that they do the inspections and then the items that they do within those intervals. And as I mentioned before, a steam generator has many components and many inspection items.

So you can't just talk about the steam generator as a singular component. You have to break it down into the items that are being inspected and how those influence your data points and your distribution of inspections. Next slide. And that's what this eye chart is.

So I don't want anybody to focus on that they can't read the left side or the right side. I want to make sure you understand the purpose of this slide. On the left-hand vertical -- the vertical access left-hand side would be 61 operating plants. There's no plant names in there.

But these are the operating plants of the U.S. fleet. And on the far right for each of those rows is a red block. And that's basically the end of their current operating license.

So you can see the operating fleet is not going to turn off all at the same time. It's a pretty significant cascading effect from today in 2024 all the way out to 2053. So what this graph is showing as I explained before about how inspections are performed is if we start with what is shown there in orange, each one of the colors designates a 10-year interval or a 10-year inspection interval.

So the orange are the current operating intervals, and then the blue is the next successive 10-year inspection interval. And if it gets to gray or green, those are, again, successive 10-year intervals for each of the plants. What you see there designated by the Xs are actually periods within the intervals of when inspections are going to take place based on the current 10-year ISI inspection interval for the entire fleet.

And I'll just point out that there are a lot of Xs and that there are a lot of Xs distributed quite evenly across the range of operating fleet. And each one of those Xs is actually not just an X. But it has multiple inspection components associated with each one of those Xs.

So there are a lot of inspections taking place over a wide range of time. And that's the purpose of this slide. But we, the industry, had to get to a point where we understood where inspections were happening, how many were happening, and when they were happening from a distribution standpoint.

And that's what this slide helps us

understand. Next slide. So this is just another representation. And this is, again, all steam generators.

But this is year 2024 through 2053. These are the number of steam generators that we'll be experiencing inspections for each calendar year between now and 2053. And again, you can see the distribution there is pretty significant. And it does taper off and it makes sense that it tapers off because you have an operating license that expires and no more inspections are taking place.

But that distribution as you get out in time still supports a level of data points and inspection distribution to give you a level of a confidence that you are inspecting at a frequency that is adequate to provide that level of liability and safety for the operating fleet that's left. And I'll just say that again these are based on a single steam generator component and not necessarily the list of inspection items that are associated with that component. So for instance, a steam generator may have one, two, three, four, four or five nozzles on a steam generator.

Each one of those nozzles has a weld. Each one of those nozzles has an inner radius. So that could be ten inspections for that single steam generator.

That's not representative of the numbers here. But we do have that represented later in the slide of this presentation. And that is actually what was represented earlier when we talked about the 2,000 and some steam generator inspections.

So the steam generator itself and the inspection components that are associated with it were in that large number of 2,000 and above examinations that took place. Next slide. So all this performance monitoring begs the question on how many, which ones, and when. And that really answers the concerns of the NRC from a performance monitoring standpoint.

And that's what we're going to review here in the next couple slides. So with the survey that was performed of the entire fleet to the end of their operating license, and those were the red blocks at the end of that big eye chart that I showed you. There are 930 inspections left to be done across the U.S. fleet of all the steam generators that are in operation.

MEMBER HALNON: Robert, that's specific types, not just --

MR. GRIZZI: Yeah, specific items. So

it's either a weld or an inner radius exam or a vessel. I'm sure vessel is there.

MEMBER HALNON: So there's no double up where some are --

(Simultaneous speaking.)

MR. GRIZZI: No.

MEMBER HALNON: Those are discrete pipes that you're talking about.

MR. GRIZZI: They are, yes, discrete items.

MEMBER HALNON: Could be two welds on a pipe?

DR. RUDLAND: It's not a pipe.

MR. GRIZZI: Yeah, it's a nozzle, but yeah.

MEMBER HALNON: On a nozzle, yeah.

MR. GRIZZI: I understand what you're saying, yes. They are discrete, yeah. There's typically not two welds on a nozzle. But a nozzle does include a weld and then it does include the inner radius. Those are two separate exams on one nozzle.

MEMBER HALNON: Okay.

MR. GRIZZI: And it could include both those exams. And that's what is reflected in this 930 number.

MEMBER HALNON: Okay. And so that would be two for that, 930. There could be two on a single nozzle.

MR. GRIZZI: Yes, yeah.

MEMBER HALNON: Looks like a pipe.

MR. GRIZZI: Understood. But they're all round.

MEMBER HALNON: It's curios --

(Simultaneous speaking.)

MR. GRIZZI: So just doing the simple math, and again, the NRC is going to talk about the binomial distribution model. But basically what it comes down to is the binomial distribution model criterial is about 25 percent of the current schedule and inspection plan for the entire fleet which is where that 232 number comes from. So basically, 25 percent of 930 is the 232.

So the proposal for the performance monitoring fleet would be instead of doing the 930 examinations that they can do the 232 examinations and still be well within -- from a conservative measure, well within the bounds of the statistical relevance of data points. And then we have to get and talk about the distribution of those data points. So that 930 would then be reduced to some other number less than

930.

And I'm going to talk about that in the next two lines there. But the total number of fleet-wide performance monitoring inspections right now being proposed by the industry will actually be 308. So as you can see, 308 is greater than the 25 percent criterion by a factor of 33 or by a factor of 8 percent or so.

So what we're looking at is the industry is looking at proposing that they do 308 exams versus 930 exams based on the statistical relevance and the right distribution without any adverse impact on the quality or the reliability of these operating assets. Next slide. And this is a -- there's a level of logic that goes into which items should be inspected. And that's what this slide is trying to illustrate.

So when applying the model, the NRC model for the number of exams that should be conducted per plant, it could range anywhere between 2 and 17 on average. But it's usually about 5 per unit. So Plant A could have 2 exams on a steam generator, but Plant B might have 17.

And that's -- it's a design-specific thing and it's a code-specific thing. So the code dictates how many inspects per your design. But on average, it's about 5 per plant. And then --

MEMBER HALNON: Just to clarify my own thought. The two circles you have there, is that three exams or just one or two?

MR. GRIZZI: It could be two. And I say that because the circle on the left shows two different weld configurations. That could be part of a design. Typically, you'd only have one of those.

MEMBER HALNON: One or the other.

MR. GRIZZI: Or the other. And then on the other side, yes, that's one. So those would be potentially two separate exams depending on the design. In this case, though, we're only talking about the tubesheet weld which is the weld that goes around the tubesheet of the steam generator and the vessel itself. So that's just one inspection item. And there could be --

MEMBER HALNON: It's a real big one.

MR. GRIZZI: It's a real big one, yeah. And so in terms of which ones are inspected is important as well. We felt that the industry needs to take an approach that has some logic and some rationale behind it.

And what we did is we went back to the technical bases and we defined of the inspection items, whether it was a weld or a nozzle radius or a pressure vessel weld itself, which ones had the highest stress concentration paths. Which ones produced the lowest number from a probabilistic fracture mechanic standpoint and a sensitivity standpoint with conservatism built in. Which ones are the most probable even though none of them are below the threshold.

Which ones are the most probable for failure. And those are the ones that we actually prescribed in terms of which ones needed to be part of the population when utilities could use these examinations. So they aren't able to just go choose any of the welds or any of the components.

They have to choose at least two or three of the ones that are being suggested based on the finite element models and the analysis work that was done. Next slide. And this is just an example. If you remember the chart from before, this is just a slice of it.

And it's look at just a short time frame within that actually bigger chart. And the only thing I'm trying to illustrate here is that you see the magenta Xs that were in place for the steam generators. Well, if you look at the bottom image, you'll see there's a bunch of green Xs.

And you can see there's a lot less green Xs. And that is just to illustrate that a reduction in inspection data points could be shown as a contrast between these two images. You still have distribution.

And that's the key is making sure that we have the right data point. We know we have the right number of data points. We need to make sure that they are distributed accurately to make sure that we have consistent data coming in across the operating experience of these different plants.

And that is to address the safe operation of these plants to make sure that we are not missing anything. The unknowns for those that we can see or that would be -- that may appear during these inspections that we're doing enough of them and distributed evenly enough to be able to catch that from a fleet-wide perspective. So next slide. So the next step for U.S. industry is put together this topical report.

And again, this is going to be very similar to what was done for the fleet for the reactor pressure vessels. EPRI is going to help the industry put together a topical report. That topical report is going to be something that is submitted to the NRC for review and safety evaluation.

NEI is also involved with this in terms of the communication aspect of it and gaining the acceptance and the buy-in at the CNO level, the executive level from the utility. So when we put forth this proposed performance monitoring plan, of course, all the utilities need to comply with the inspection that they've been assigned. And that's very much, like, what happened to the reactor pressure vessels.

So there's an element of this topical report that will have what we're calling a Letter Addendum. The Letter Addendum is actually the vehicle which will perform reviews on a periodic basis or reviews as things change in operating license of the fleet. And those, that Letter Addendum will be a reassessment or reevaluation based on those two criteria that we just talked about.

Do we have enough data points, and are they distributed correctly? So that's how we're going to handle that from a mechanics standpoint. And I think that's it, yeah. So that's the end of the presentation. Is there any questions?

MEMBER DIMITRIJEVIC: Yeah, I have a

question. This is Vesna Dimitrijevic again. You had the items to be examined. They're going to choose from the most critical stress paths, right?

MR. GRIZZI: That's correct.

MEMBER DIMITRIJEVIC: And also from results from the fractured mechanics codes, right, showing the highest probability of failure. Do you have data from the previous steam generator examinations? I mean, the findings before the 2024.

MR. GRIZZI: I'm not sure I understand.

DR. RUDLAND: Inspection, prior inspections. Do we have the data from the prior inspection results?

MR. GRIZZI: Before 2024? Oh, yeah. So prior to 2024, we do have -- yeah, the surveys that we did were good through 2019.

MEMBER DIMITRIJEVIC: Okay.

MR. GRIZZI: But we do have or we can collect the data between 2019 and 2024. But what I can say is that there had been no indications reported in that five-year time frame. We absolutely would've been notified if that were the case.

(Simultaneous speaking.)

MEMBER DIMITRIJEVIC: And how many indication -- you have -- how many indications you have after the 2019?

MR. GRIZZI: Zero.

MEMBER DIMITRIJEVIC: So you actually have no indications on any of those inspections?

MR. GRIZZI: That's correct.

MEMBER DIMITRIJEVIC: Okay, all right.

MEMBER HALNON: Robert, I was going to ask the initiative through the NSAC or NEI, whoever is going to -- however they're going to do it, will they just parallel the same type of process for the reactor vessel in terms relative to reporting and making sure that NRC is involved, a corrective action program, all of that, that's going to just parallel all through that?

MR. GRIZZI: It should parallel what was done with the reactor pressure vessels. And NEI, their -- we've been working again with NEI as well from a communication aspect and input from the industry standpoint. But yes, they were parallel what was done with the RPV.

It might be a little different. We need to make sure that we're doing this smartly because the RPV inspections don't necessarily change or not necessarily as dynamic as what we're doing with the steam generators and pressurizers because of the number of examinations and because not every plant only has one steam generator. So plants typically have two, three, or four steam generators.

So some of that enters into the data points and the distribution. So from how we plan to handle this with a topical report is that the topical report will talk about the process and approach and how we got to where we are today. The Letter Addendum will be the vehicle which we use to update the status of the industry and make sure that we are not necessarily broaching the two items that concerns the NRC in terms of distribution and number of data points. And that will be something that the executives of the utilities will have to comply with.

MEMBER HARRINGTON: This is Craig Harrington. Is that going to be a living document, the Letter Addendum? So that will evolve as plants shut down or start up --

(Simultaneous speaking.)

MR. GRIZZI: Yeah, absolutely. And that was the -- sort of the reason the structure it poses because we don't want to have to go through a topical report review every time that there's a license change or there's a review period. We want to be able to reference that Letter Addendum and then use that as the vehicle for change. And the approach hasn't changed. We're still meeting the elements of the topical report. We're just making sure that if the change has a negative effect that we can put the brakes on to make sure that we're not necessarily breaching those two areas of concern.

CHAIR BALLINGER: This is Ron Ballinger. We've got two examples, the steam generator and the pressurizer. Is this methodology intended to be used for other components down the line?

MR. GRIZZI: I would say maybe, but probably yes.

(Laughter.)

PARTICIPANT: Definite maybe.

MR. GRIZZI: Well, so you know there's --

CHAIR BALLINGER: What's the probability of that?

MR. GRIZZI: Yeah, I don't know what the probability is.

CHAIR BALLINGER: Yeah, 95, 95.

MR. GRIZZI: There are a couple other components in the component list that we looked at that could potentially follow suit. But we're not 100 percent sure yet. This is the first venture into the performance monitoring for fleet-wide approach since we did the reactor pressure vessel head. So it's a little bit different. Except that we know that the proposed plan is acceptable.

MEMBER MARTIN: I was going to have a simpler question but more specific like safety relief valves, something like that, whether this could come into play.

MR. GRIZZI: Not an item that we focused on necessarily. But certainly the methodology and the analyses tools, the methodology of those approaches certainly can be applied. It's just a matter of do they actually bring anything of value to fruition, right? You might get that answer you don't like, right?

CHAIR BALLINGER: But you don't need fracture mechanics if you've got zero data. If you don't have any indications, this is not a PFM problem. You have no indications.

MR. GRIZZI: Right, yeah. There's no indications. But I mean, you still have to -- the materials, they're performing, right? Like, there's still material performance considerations they have to take into account and you do have to make sure that material performance is being backed up by inspection. So I think that is relevant.

DR. RUDLAND: Even if there's no indication, there's always probability that you can have an indication. And so you can always do PFM analysis. You have a probability --

(Simultaneous speaking.)

MR. GRIZZI: Scientists love that.

CHAIR BALLINGER: I hate to get academic about this, but it's an initiation plus propagation issue.

MR. GRIZZI: That's right.

CHAIR BALLINGER: The propagation part, the PFM handles well if you have data. It's the initiation part that is sometimes a black art because when you fabricate these plants and you do the welding and everything, it's just a very difficult thing to deal with. So if it's initiation plus propagation thing, you kind of have to assume that at some point you're going to get an event.

And then it's the propagation part that becomes important. And then you have to make sure that your inspection interval coupled with either other things that you do like we do, do at plants. We do walkdowns. We've got unidentified leakage things. It's curious. When I see the word failure, I don't think you're meaning pipe rupture.

MR. GRIZZI: No, you're right. You're right.

CHAIR BALLINGER: Okay. So it's not pipe rupture.

MR. GRIZZI: Yeah, you're right. And if you look at the reports actually and the analysis, we start from a flaw --

CHAIR BALLINGER: Yeah.

MR. GRIZZI: -- propagation standpoint. We start with a postulated flaw size, right, and then run it through as probabilistic fracture mechanics and say, how is it going to grow? How fast is it going to grow? When did it grow? So the failure criteria in these cases were considered leakage but only 80 percent through-wall.

CHAIR BALLINGER: Yeah.

MR. GRIZZI: So yeah.

CHAIR BALLINGER: So there's a built-in conservatism here --

MR. GRIZZI: Yes, absolutely.

CHAIR BALLINGER: -- that's unsaid. But that's the way --

(Simultaneous speaking.)

MR. GRIZZI: It said in the reports.

CHAIR BALLINGER: Yeah, yeah.

MR. GRIZZI: But yeah, yeah. We didn't -- I didn't -- I failed to mention about the failure. But yes, that is a -- the criteria for failure leakage is considered 80 percent through-wall from a postulated flaw that has grown over time.

The consideration for an event where initiation occurs is also done in the probabilistic fraction mechanics analysis work. And off the top of my head, I can't remember all the different parameters and variables were. But there were a lot of sensitivity studies run in conjunction with that as well.

DR. RUDLAND: You have to make a decision on how conservative you want to put your model based on your expected uncertainty. So if you're not certain about initiation, instead of trying to model that big uncertainty, you just assume conservative flaw that is there at the beginning, right?

CHAIR BALLINGER: Well, that's what everybody does, not just our industry. Okay. We are actually -- we have to do something to ruin this. We're actually on schedule. So we're scheduled for a break at 2:30 and it's pretty darn close. So let's break until 2:45.

DR. RUDLAND: If I can just ask. Dave

Dijamco is next after break. Do you want to share your screen? Or do you want me to share slides, Dave?

MR. DIJAMCO: Hey, Dave. Can you run the slides?

DR. RUDLAND: I can, yes.

MR. DIJAMCO: Okay. Thank you.

CHAIR BALLINGER: Okay. So we'll come back at 2:45.

(Whereupon, the above-entitled matter went off the record at 2:32 p.m. and resumed at 2:48 p.m.)

CHAIR BALLINGER: Okay. We're back in session. So I don't know who is up actually. Dave -- oh, there's the first one.

MR. DIJAMCO: Am I on screen? Can you guys see me?

CHAIR BALLINGER: Yeah, yeah.

MR. DIJAMCO: Okay. Thank you. Okay. I'm going to go ahead. So good afternoon, My name is Dave Dijamco. I'm a technical reviewer in the Vessels and Internals Branch in NRR.

So I've been involved with reviewing the submittals associated with the EPRI reports that Bob discussed earlier. And I'm going to talk about specific applications of the use of these reports within the PFM and risk informed decision making framework that Dr. Rudland presented. So next slide. So my presentation is divided into three topics.

First, I'll talk about the PFM aspects that the staff focused on. So I'll cover things like the PFM acceptance criterion, the audit of the PROMISE PFM computer code, sensitivity studies, criteria for plant-specific applications. And then I'm going to move on to talking about performance monitoring.

I'll talk about the statistically determined inspection sample size. And then finally, I'll talk about the plant-specific applications. And then we're going to focus on the pressurizer and steam generator vessel welds and nozzles for single and two-unit plant submittals as well as fleet submittals. Next slide.

So before I dive into that topic, I just want first list precedents for the use of PFM with adequate performance monitoring. And these are all for vessels because that's the component I work with in my branch. As you can see in all these examples, there is a PFM piece and also a performance monitoring piece.

And really this slide is simply a reminder that the PFM plus performance monitoring approach is really nothing new. Next slide. So the PFM aspects the staff focused on started with the acceptance criterion. The criterion is 1e to the -6 failures per year, and this is consistent with the basis during development of the alternate pressurized thermal shock rule in 50.61(a) in which the reactor pressure vessel through-wall crack in frequency was conservatively assumed to be equivalent to an increase in CDF.

This is conservative because in reality an increase in RPV through crack in frequency does not necessarily mean an equivalent increase in CDF. Lots of details in this one NUREG-1806, and that's the technical basis for the revision of the PTS screening limits. And this criterion is used in the PFM analyses in EPRI reports that Bob discussed earlier.

They are the two reports for the steam generators and the one report for pressurizers. So while pressurizers and steam generators are safety significant, they're not safety significant as the RPV. And therefore the staff finds that it's appropriate to apply this 1e to the -6 failures per year criterion for these analyses. Okay. Next slide.

So the PFM analyses in the EPRI reports were performed with the PROMISE computer code as was mentioned earlier. The staff conducted an audit of the code. So PROMISE stands for probabilistic optimization of inspection. It was a two and a half day audit.

And the objective here was for the staff to understand how the PFM principles were being applied. Were they consistent with guidance? And we refer to the guidance in the Reg Guide, Reg Guide 1.245.

This is the guidance for PFM submittals. And we looked up various things. Listing here are some of the prominent ones, inputs and models. So we -- for models, we not only looked at the probabilistic models, for example, the mean and standard deviation values of your distributed variables, but also the non-probabilistic models, for example, your finite element stress analysis, your stress intensity factor solutions, and as well as in service inspection and examination coverage.

We also looked at uncertainties, convergence, software V&V, and sensitive duty studies. Next slide. So the staff observed five key aspects during the audit. And all these aspects were adequately addressed.

And I'm going to basically go over these in the next few slides. Okay. Next slide. So software V&V followed the ASME NQA standards for V&V

as well as the guidance from 10 CFR 50 Appendix B. A software V&V plan and V&V reports were generated, and the staff made sure that the plan contained testing of the various parts of the software and that the testing results were adequate and reflected in the reports.

So for uncertainties, the mean and standard deviation values of the rounded variables, and again, these are the variables with a probability distribution rather than a single value. We made sure that those were consistent with previously accepted values. And I listed some of the parameters here that were treated as random variables in the analyses. Next slide.

So initial flaw distribution, I assigned an exam coverage. So for the initial flaw distribution, it was based on what's called the Pressure Vessel Research User's Facility, otherwise known as PVRUF. It was an unused RPV.

And the flaw distribution from -- the flaws from distribution was developed from the NDE of fabrication flaws in the vessel weld. And it consisted primarily of small surface breaking flaws. This flaw distribution was also used in the BWRRVIP-05-based submittals for the circumferential RPV welds.

So staff also insured that ISI and

examination coverage -- and by exam coverage, we mean here the examination of the weld volume. We made sure those were modeled since these are key aspects of the ASME Code Section XI examinations. For the ISI model in short, it was implemented through a probability of detection curve at the times of inspections.

For the exam coverage model, that was implemented by allowing the model postulated flaw to grow for a number of realizations during the PFM run that's proportional to the coverage missed. Next slide. So sensitivity studies, so I think sensitivity studies is one of the important concepts from the Reg Guide 1.245 guidance. Basically, you establish a base case and determine the most critical parameters.

Now in this case, it's no surprise that stress and fracture toughness are the critical parameters that came out because those are the parameters for fracture mechanics. And they correspond to the driving force and material resistance. And so from this base case, you do a sensitivity study on them on the parameters to see how the PFM results are impacted.

And so for this particular case, a sensitivity study on stress of up to more than twice the base case stress levels and fracture toughness that I should say down to less than half the base case fracture toughness were performed and showed that the acceptance criterion, 1e to the -6 failures per year, was met. Next slide.

MEMBER PETTI: Dave, just a question.

MR. DIJAMCO: Yes. Oh, yeah.

MEMBER PETTI: Were those changes at the same time or two separate sensitive runs?

MR. DIJAMCO: They were two separate sensitivity runs, but there was also a section on where they combined stress and fracture toughness. So they did both. So actually it will be three times, then. So they did sensitivity study on stress, sensitivity studies on fracture toughness separately, and then they did a separate one that did a sensitivity study combined stress and fracture toughness.

MEMBER PETTI: Okay. Got it.

MR. DIJAMCO: So criteria for plant-specific applications. So the EPRI reports were based on representative or conservative geometric configurations, representative or conservative transients or cycles, and that was based on a survey of PWRs, as Bob discussed earlier.

So that's -- there's a need for criteria

-- criteria for the following parameters in a plant-specific application, parameters such as geometry, materials, loading conditions, things like that.

Next slide?

So for the subject EPRI reports, Chapter 9 contains plant-specific criteria that must be met, and the submittals must include information how they meet these criteria.

So the staff also evaluates the plant specific inspection history, and this means the number of in-service inspections that were performed and also the examination volume coverage.

So just a little bit on this last point, so as I mentioned earlier, ISI and exam coverage were modeled, so sometimes we'd see submittals with very low examination coverages, and we want to make sure that if those are very low that it's properly addressed in the submittal; for example, with a plant specific PFM run with a specific examination coverage.

Next slide?

Okay. So I talked about PFM, which addresses the risk principle of risk-informed decision making. So now I'm moving into performance monitoring piece of it.

So performance monitoring supports RIDM in three ways. It provides direct evidence of presence and extent of degradation, provides validation of the continued adequacy of the analyses, and it provides a timely method to detect novel or unexpected degradation.

So now with respect to the subject analyses and reports, the staff focused on the PFM, plus the performance monitoring principles, because those are two monitoring -- those are the two most prominent principles that needed attention. But the question is: what about the other three principles of RIDM? Maintaining safety margins, maintaining defense-in-depth, and compliance with regulations.

So, summarily speaking, safety margins and defense-in-depth, those primarily have to do with design, and the design parameters -- things such as material properties and operating characteristics -- those are not changing. Also, the multiple means to accomplish your safety functions, which in essence is defense-in-depth, those are also not changing.

MEMBER PETTI: But, Dave, just a question. But our perception of them might have changed, correct? Go -- before probabilistic fracture mechanics, there was some sense of safety margins and defense-in-depth in a design based on, I don't know, some deterministic, you know, approach.

Now you've got a much better tool that may in fact suggest greater margin or confirm your margin I guess. But it doesn't -- it informs you, so you have more knowledge. So how you think about the safety margin and defense-in-depth might change.

MR. DIJAMCO: Sure. Sure. I think, yeah, that's -- I think I would tend to agree with that, yes. Yes, that's -- that's correct.

Now, with these probabilistic tools, more sophisticated tools are coming out -- you know, out there, so, yes. So once you use these PFM tools, I think there is some sense of the change or perception. So that's correct.

Yes. I think I'm on the -- so, basically, what I tried to conclude on this slide is that these other three principles are relatively minor players compared to PFM, again, which addresses the risk principle and performance monitoring.

So next slide?

So before I go into how the staff determined an adequate inspection sample, I first want to illustrate interval extension, since, as Bob discussed earlier, the EPRI reports were used as a basis for interval extension. And I believe Bob used the term optimize interval.

So the top features there represents the ASME Code 10-year ISI interval. It's divided into thirds, and you have a specific amount of inspections that need to be performed in each third. And that bottom figure is an extended interval.

So, as you can see, performance monitoring is really built into the -- into the ASME Code Section XI ISI interval. However, with interval extension, inspections don't disappear, but it's really not clear how those inspections play out. And it doesn't necessarily mean having this every third scheme.

So we know that we're going to have fewer inspections with internal extension, and the question is, what inspection sample size is acceptable?

So next slide?

And that's really the question that we're trying to answer here using statistics. So a quantitative sampling calculation can be derived from a statistical calculation -- from a statistical calculation. I'll go over this in the next few slides, and we use the methods of the binomial -- the binomial distribution and the Monte Carlo analysis.

So what are we trying to do here? So, at the conceptual level, the objective is to determine the sample size -- in our case, that's the number of inspections -- from a population of like objects that gives a certain probability of a success outcome. And here our success outcome is detection of your degradation, assuming a certain percentage of the population has this characteristic for your success outcome. And, for our case, this characteristic is being degraded or cracked.

So the staff described the details of these methods in a PVP paper authored by our very own Dr. Rudland and Dan Widrevitz, and this will be revisited again in the guidance presentation later.

Next slide?

With the binomial distribution, it's frequently used to model the number of successes of sample size N drawn from a certain population size. So in the binomial there are only two outcomes, either success or failure.

So the binomial can be used to find the number of inspections needed to find a crack, and it's independent of population size.

Next slide?

So the same concept here can be applied with a Monte Carlo analysis, but with the Monte Carlo it allows -- it's a little bit more general. It allows for maximum flexibility in the analysis, and you can actually recreate the binomial response with the Monte Carlo, as you can see in that plot there. And also, as you can see in this plot, the Monte Carlo works better for smaller populations.

So another thing to note in this plot is that the binomial is really well-suited for a large population, as you can see in that comparison plot with the Monte Carlo, even though population size does not even enter into the equations of the binomial.

So next slide?

Okay. So the staff contemplated whether the results of the statistics, be it your binomial or Monte Carlo, should be applied to a population of welds or to whole components.

So the ASME Code specifies a suite of welds to be inspected for a specific component, for example, for a pressurizer as shown here. An X number of one type of welds are required to be inspected, and a Y number of another type of welds are required to be inspected.

So this figure shows the pressure of their bottom head on the left side. You have the top head on the right side, and you can see clearly from this these two figures that the weld configurations are very different.

They can also experience very different stress levels and also potentially very different surrounding environments.

So the binomial and the Monte Carlo assumes that the objects in the population are more or less identical. So, at the weld level, the resulting sample size may not be true to this assumption.

Next slide?

So, therefore, for simplicity, the staff considered component level when applying the results of the statistics, because the components at the component level, be it, you know, a pressurizer or steam generator of the fleet, are more or less identical in terms of configuration, materials, and operating environment, albeit of course some slight variations in the three NSSS designs.

The thing to remember, though, about the component level is that inspection of the whole component means inspecting the whole suite of welds that's required to be inspected for that component.

So next slide?

So taking the binomial and the Monte Carlo concepts at the component level, let's go through an example of how the staff calculated an adequate inspection sample size for pressurizers.

So you have population size and 61 pressurizers. That comes from 61 PWRs in the U.S. fleet, having one pressurizer each. We're going to assume that five percent of that population is degraded or cracked, and we're going to design a 90 percent probability of detecting at least one crack in the population.

So we run these numbers. We get into the binomial or Monte Carlo. We crunch the numbers, and we get a 25 percent of the population of pressurizers.

Next slide?

So what does this mean in terms of submittals? So these examples I'm showing here on this slide are very simplistic. So I'll go over an example from an actual submittal in just a few moments.

So a submittal with one unit requesting three 10-year intervals, that results in three pressurizer inspections. That's required by the code. You take a 25 percent sample of that, and you can one pressurizer for a performance monitoring sample, and that's rounded up.

If you have a three submittal, let's say, with 10 units, are requesting three 10-year intervals, you get 30 pressurizer inspections. That's required to be inspected by the code. If you take a 25 percent sample, and you get eight pressurizers for a performance monitoring sample. And, again, that's rounded up.

Next slide?

So just a note on timing of the performance monitoring inspections, so for illustrative purposes, let's say you're the third interval, you've just finished your last set of inspections, and that's represented by the dark square there. And you've been approved for an extended interval.

It's not generally a good idea to do your performance monitoring sample close to that last inspection. What you want to do is space them out, do them later during the -- later during the extended interval, because later inspections have more chance of detecting degradation if it is present than earlier inspections, since the degradation -- the degradation has had time to develop to a level that is detectable.

Okay. Next slide?

So I just have a few slides here on plant specific applications. So applications -- we call them also submittals -- have been coming in pursuant to 10 CFR 50.55a(z)(1) requesting to extend the intervals, and they refer to the EPRI reports as the technical basis.

So the basic staff approach on evaluating these, so we ensure that the PFM is consistent with the technical basis reports, especially that the -- that the submittal meets the plant-specific criteria covered earlier. Again, those are the two reports for the -- for steam generators, and the one report for pressurizers. And we also evaluate that the performance monitoring sample that is proposed is adequate.

Next slide?

So single or two-unit plant submittals, so these submittals are for one or two-unit plants proposing to extend the code-required interval for up to three 10-year ISI intervals. They refer to the EPRI reports for the PFM technical basis and provide an adequate performance monitoring plan.

So the staff goes through the evaluation process with -- for the items that I talked about earlier. But for these single and two-unit submittals, they are really not as intriguing as the fleet submittals, so I'm not really going to go into them much more than this. So I'll just jump right into the fleet submittals.

Next slide?

Okay. So fleet submittals. So the submittals are for multiple plants, thus for multiple units, proposing to extend the code-required interval for up to three 10-year ISI intervals, same technical basis, the EPRI reports for -- technical basis for the PFM.

So as with the single or two-unit submittals, we make sure that the PFM is consistent with the technical basis reports. We make sure each unit meets the plant-specific criteria, and we evaluate the in-service inspection history and exam coverage.

But with the fleet submittal, the proposed performance monitoring gets really interesting, because now you have different alignment of the ISI intervals -- the intervals of the various plants.

So next slide?

So this is just an example of a proposed performance monitoring plant -- plan we have seen in a submittal. It's for a nine-unit fleet, and this kind of gap-like figure or chart is very helpful in visualizing what's going on. You can see how the intervals align, or in this case misalign, and you can see the timing of the inspections. They are spread out, and they are also giving a good stream of data.

So, for this particular case, the performance monitoring sample is represented by the axis as you can see there in the orange regions, and also you notice there for three units the ASME-required inspections resumed, and that's represented by the blue -- by the blue regions there to the far right of the figure. And that basically means three full pressurizer inspections.

Okay. Next slide?

So this slide shows an example of how the staff confirms an adequate performance monitoring sample for fleet submittals. So the top table there is the calculation of the code-required pressurizer inspections. So the requirement is one pressurizer per unit per ISI interval.

So that first row you have two units. It's applied with two units requesting a two-interval alternative, and that results in four pressurizers that's required to be inspected for that specific plant.

And so you just go down the rows for each of the other plants, and you end up with a total of 14 pressurizers that's required to be inspected for the specific fleet submittal. You take a 24 percent sample of that, that gives three and a half, and that rounds up to four pressurizers for a minimum inspection sample size.

So the bottom table is the calculation of the proposed sample size. So for this particular case for each unit one full pressurizer consists of 10 weld. For this particular case, the licensee proposed to perform two weld exams for their performance monitoring exam -- performance monitoring sample for that particular unit, which gives you a 0.2 percent pressurizer equipment.

So this concept of a pressurizer equivalent is basically giving credit for a fractional pressurizer inspection. So now you go, to sum them up, you sum up the pressurizer equivalents. That gives you one, and you add the three from the previous slides, the three full pressurizer inspections from the previous slides, and that gets you to your minimum of four sample for a performance monitoring sample.

Okay. Next slide?

So, as a final slide here, just a quick note on that guidance. There have been 15 or so submittals for pressurizers and steam generators since the first submittals. We actually have a lot --

something like maybe I would say seven in house right now. So this approach also has been taken for other components, as Bob discussed earlier.

Examples -- heat exchanger vessels and also for the reactor closure head studs, but with the studs, though, the technical basis is deterministic fracture mechanics rather than probabilistic.

So these clearly bring up the question: is the staff developing guidance? And I hope the answer is clear, it's a resounding yes, and hopefully that ubiquitous logo that you've been seeing on my slides and also on Dr. Rudland's slides help drive the point.

CHAIR BALLINGER: That was the basis of a question that I asked earlier about whether this method would be applied to other components, because that's actually, in my mind, a reason why we're having this debate. It's not just the steam generators and the pressurizers, so --

MR. DIJAMCO: The binomial and the Monte Carlo doesn't really care where it -- as long as they meet the assumptions of that model, at least that's what I think.

MR. GRIZZI: Yeah. I guess my answer was we don't know if it will be successful, right? And in this case, we have a pretty good idea it will be successful, but you might run into other components where that might not give you the answer you're looking for. Right? In terms of being able to optimize something, yes.

DR. RUDLAND: I can also say that there is code cases floating around in draft form in the ASME Section XI right now to change the inspection interval or even an alternative to the inspection interval for many components. So they are trying to incorporate this stuff into code also.

CHAIR BALLINGER: Walt?

MEMBER KIRCHNER: Yes. Thank you, Ron.

David, what happens if you have a bad inspection? This is all success-oriented. If there is a bad inspection with a serious degradation or flaw, does that change the calculus?

MR. DIJAMCO: I would say no, because if you have an inspection, that will be -- that will be handled by the actions that's specified in the -- in Section XI. So for the -- for the model in the PROMISE Code, so you go through -- remember I said earlier ISI is modeled.

So whenever you have the ISI model, you go through the probability of detection curve. And when you detect a flaw, you assume that -- well, if it's really bad, you assume that it has been repaired, through the actions of the code. And, therefore, it will not continue to grow to a level that can cause failure.

MEMBER KIRCHNER: Well, a critic might say, an observer might say, well, you know, where you have, like, two units or in one case three units that are nearly identical, most of the plants really weren't standardized, so they're really different.

How does your algorithm address that aspect? That's why I say if there were to be a fault, a serious degradation or something detected, how would that change it? It seems to me that would have an impact at least -- obviously, you know, it would be a flag for the NRC as well as the industry, and probably merit, obviously, as you say further requirements according to the ASME Code. But I'm just -- I'm just thinking, we're not dealing with a big population.

MR. WIDREVITZ: So I'm going to address several aspects of this question. I'm sorry. This is Dan Widrevitz of the U.S. NRC. And this is -- it's actually something that we were concerned with, particularly for the fleet submittals.

So the fleet submittals were going down to

25 percent sampling. And in concert with that, one of the things that we discussed with the applicants and that you'll see in approvals is an automatic expansion criteria if you do find this evidence. Right?

So the postulate is it will take 400 years to drive a fatigue crack through some of these. I suppose that's your postulate. Right? So you're not expecting any degradation. Your statistical question is looking for, what is the physical counterevidence? If you find counterevidence, you need to expect your inspections to determine what the actual state of the population is.

And so what you'll see in the fleet submittals is they actually have expansion criteria automatic between sites if they find that sort of evidence when they're finding unacceptable flaws for the ASME Code. In addition, the ASME Code requirements within a site, automatic expansion if you find something within the site. So that's exactly something that we were thinking about when we were doing these reviews.

MEMBER KIRCHNER: Okay. I just wanted to get that on the record, that it just -- you just don't keep going along as if something didn't happen, because these are not very large statistics in my opinion.

CHAIR BALLINGER: This is actually pretty standard. I mean, the steam generator inspection people, that's a very well-established program.

Scott?

MEMBER PALMTAG: This is Scott Palmtag. Thank you, David, for the presentation. I admit, it's pretty elegant math. I just have a couple questions on how exactly this will be implemented. It is fleetwide, so who would make the determination of which plants get inspected, which ones wouldn't? Because I would think some plants would get multiple inspections and some wouldn't.

MR. DIJAMCO: So I think part of the answer there would be probably somewhere along the lines of that topical report that -- as far as implementation that soon -- I mean, still-being-worked-on topical report that's been discussed by Bob. Anybody else from the staff would like to share their thoughts on that?

MR. GRIZZI: Yeah. This is Bob Grizzi with EPRI. I'll just chime in and say that, yeah, it's still a work in progress, but that was from the presentation earlier. It was about, you know, the data points and the right distribution, and there shouldn't be or won't be any plants that are omitted from the inspections that are being done. They will be more than likely evenly distributed amongst all plants that are still currently operating.

MR. WIDREVITZ: And is this --

MR. GRIZZI: It I think referenced fleet submittals, and that was owner's fleets, half the entire BWR fleet. That's something that I was working on, so those are -- those are different things.

DR. RUDLAND: Just to give a little bit of timeline on this also, it's a bit confusing because maybe you don't quite understand the timeline of this, is that when this stuff was first submitted it was planned to do mainly on either abiding by a unit basis or on an owner fleet basis and not necessarily on a complete fleet basis.

And it was through these efforts with single-unit applications that we realized that making sure that we have adequate inspections or performance monitoring were not going to happen unless we looked at it more of a -- as a complete fleet basis.

So there is applications that have already been approved for certain single or double unit sites and several fleet unit sites, which maybe include, you know, a half a dozen or seven or something like that units. But because of those results -- that's the effort now that Bob is talking about for the future for the rest of the fleet -- is to join them up into one big program instead of trying to do them piece by piece.

MEMBER PALMTAG: So just in terms of implementation, someone is going to sit down and come up with this 30-year schedule in advance?

DR. RUDLAND: Yeah. That's what Bob showed kind of earlier in his presentation.

MEMBER PALMTAG: So how does that work with flexibility? For example, you know, some plants are going to shut down early, some may come back online. Someone is going to have to revisit this every so often, right?

MR. GRIZZI: Yeah. That's part of the discussion in the topical report would be what kind of periodic review there would be, plus what are the trigger points for an assessment or a reevaluation based on those types of events. So, you know, when a plant shuts down early, if a plant gets a license renewal, you know, that factors into, you know, the overall numbers of statistics and the distribution of examination.

So those would be taken into account, and those would be what I referred to earlier as the letter addendum. That would be the mechanism to which we make updates and review the entire fleet be -- those triggers or those periods hit for the review cycle.

MEMBER PALMTAG: Okay. And, sorry, one final comment on the implementation is, I would think that when you have the equipment onsite it would be easier to do multiple inspections at the same plant site rather than, you know, doing one inspection in one plant, one inspection in the other plant. Have you thought about that? Just in terms of implementation.

I realize the Monte Carlo is kind of elegant, but it doesn't take into account practical issues like that.

MR. GRIZZI: Yeah. And the way the plants currently do them is they don't necessarily -- so, for instance, if there was like -- if there are six pressurizer exams to be done, they will split it up based on other work activities that are associated with those as well.

So even though they have the equipment there, they might not do all six inspections at the same time. They may break it up and do three in one period and three in the third period because they are doing work where they might have to remove the insulation from the top of the pressurizer for other activities, and it makes more sense to do the inspections when they remove the insulation for dual purpose versus having to do that twice.

So there are some -- there are some logistics that are -- that factor into it, and that would be put into the consideration in the distribution as well.

MEMBER PALMTAG: Okay. Thank you.

DR. RUDLAND: There's also ASME requirements where they have to -- they have certain percentages of the weld categories after they inspected each period, so they've got to balance those requirements also. So it's --

MEMBER HALNON: Will this allow excluding certain welds that are just difficult, high dose, hard to get the equipment and personnel into, so that some welds may never get an exam?

MR. GRIZZI: It's some -- I don't know exactly how to answer that because the reduction in number of inspections that are proposed for a plant, there's a wide range of -- on the one slide you might have recognized it said between two and 17 examinations based on the reduction.

The plants that are current -- the inspection items that the plants currently inspect will be within the same samples of items that they were inspecting in the past, but the distribution may be a little different.

So it's not 100 percent determined that each inspection item will get an inspection, but because of the logic that's being applied based on the analysis work, we were looking at what is thought to be the most critical from a stress standpoint.

DR. RUDLAND: From a staff perspective -- and, again, realizing we haven't seen or reviewed this topical report, yes, you know, so -- but from a staff perspective, one of the reasons why we looked at the distribution in terms of full components, right, as Dave was talking about, one pressurizer, was so that each major weld category within a pressurizer gets eyes on it sometime, instead of maybe saying we never look at the inner diameter, or something like that. Right?

So that was the at least staff's problems, that we need to get eyes on all of the categories sometime.

MEMBER HALNON: I think that's important

is -- if it's hard to examine because of interferences, or whatever, it was probably hard to weld as well. And that introduces some uncertainty in the manufacturing part of the construction process, which even though it was dissimilar, we saw at V.C. Summer.

DR. RUDLAND: If there's an accessibility problem, there's other code requirements and regulatory pathways they can take for that.

MR. WIDREVITZ: So I can say that in the submittals that we've received so far its actual coverage is in that, and so we've seen those numbers, and they tend to be fairly high overall. We're not talking 20 percent coverage from any of these or any I don't think I see anything that low at that --

MEMBER HALNON: Even down to the examination or -- you could have liftoff and other things that occur, and you can still get a full weld. But, again, back to the case study we've been talking about, there's liftoff exactly where that crack was. But it was code acceptable examination, so --

MR. GRIZZI: So this is Bob Grizzi with EPRI again. So in the current prescribed intervals in the sampling, there are welds on particular components that never get looked at, because of the sampling methods that are used.

So, for instance, there may be a steam generator plant that never had any inspections performed because they have four steam generators at the plant, and they use one or two as their basis from a sampling standpoint. So that condition does already exist in the current ASME-prescribed intervals and inspection area. And then you fall back on your defense-in-depth, same -- manufactured by the same people, the same time, not going past 80 percent. It's not going to fall apart, and it's -- as a consequence of missing it.

MEMBER HALNON: One may argue another level of conservatism is the fact that we are dealing with low alloy steels, which is what a steam generator is, which is what the pressurizer is, which is what the RPD is. So we're almost dividing up a single category. I know there's different elements of operation, but at the end of the day material performance for low alloy steels are the same materials, are probably pretty similar. Right?

MR. GRIZZI: Pretty much the same conditions that you're seeing --

MEMBER HALNON: Right.

CHAIR BALLINGER: Vesna? Vesna?

MEMBER DIMITRIJEVIC: Hi. So thanks for this presentation. Now I understand much better how is this risk-informed part -- part of this. So I have a couple of questions about that. I'm going to go back from those -- the last.

The fracture mechanics results considered, I thought, inspections.

MR. DIJAMCO: Yes. They -- so in-service inspection -- inspections were modeled in the analysis.

MEMBER DIMITRIJEVIC: So, then, yes --

MR. DIJAMCO: I could --

MEMBER DIMITRIJEVIC: -- in-service inspections were considered. Right?

MR. DIJAMCO: Yes. Inspections were considered.

MEMBER DIMITRIJEVIC: Okay. So basically you do model changing the plan because of the change in the frequency of inspections, right?

MR. DIJAMCO: Yes. Yes.

MEMBER DIMITRIJEVIC: Okay. Now let me just ask this. Also, I was curious, where does this -- the where it comes from, is that comes from the loading conditions?

MR. DIJAMCO: Can you --

MEMBER DIMITRIJEVIC: Where does the unit come from? Because, you know, there is a probability of failure, but there is some -- you mentioned in frequencies, and that -- where that frequency comes -- is that based on assumptions on the loads?

MR. DIJAMCO: Is a frequency --

MEMBER DIMITRIJEVIC: Less --

MR. DIJAMCO: Well, the stress comes from the finite element analysis, stress analysis.

MEMBER DIMITRIJEVIC: Well, are you -- do you assume -- so is this stress assumed in the air? Is that how it's done? Is that where units come from? And because my question is, does this occur on demand when the event occurred or we challenge that? Or is it just some average yearly conditions was considered?

DR. RUDLAND: Dave, if you don't mind, let me take a shot.

MR. DIJAMCO: Yeah. Sure.

DR. RUDLAND: This is Dave Rudland. The failure that -- the probabilistic fracture mechanics is a time-based solution, so it allows us to calculate the failures as a function of time, and that's where the frequency comes from -- for failure frequencies, from -- right from the finite element or right from the PFM analysis.

And that would include all of the relevant conditions for any particular run, whether it's in service inspection or leak detection or any mitigation that had occurred in those calculations.

MEMBER DIMITRIJEVIC: So this -- so because I participate in this Yankee Rowe pressurized thermal shock study, we calculate failure probability given the challenge to the vessel, you know, the challenge which created pressurized thermal shock conditions, you know, cool down and things, and that's where frequency came from. So, in that case, the fracture mechanics part came as a probability, not as frequency. So I was actually calculating, but we didn't -- I don't know, did they use the finite elements or what was the part.

So this is why I was curious about. So, basically, you -- this is the -- okay. Well, I mean, I have to think how that applies. And did you consider that also just -- you consider only core damage, not the releases, in those events?

DR. RUDLAND: These solutions do not look at core damage. They are not PRAs, right? So there is

MEMBER DIMITRIJEVIC: No. I totally understand. You're just using this 10 to minus 6 from

1.174.

DR. RUDLAND: That's correct. Right.

MEMBER DIMITRIJEVIC: But my question, but you know that number is different for releases. It's 10 to minus 7, so I was curious, does -- is it assumed that either vessel or steam generator failure will not cause the containment bypass?

MR. WIDREVITZ: So I think I can get a couple of these. The PFM was essentially modeling fatigue from the distributions of its input variables. That's how you can say what likelihood overall of the simulations you have -- do or do not have a leak or rupture. That was it. They were calculating leaks or ruptures.

And if we can survive a fair number of even having a leak or rupture is low enough, we never have to talk about CDF or LERF. They are simply irrelevant. It's low enough that they -- calculating them would be an even smaller number, right? And so they didn't need to go that far into questioning and do that much modeling.

They just said we can -- you know, we have these really -- based on our current understanding of these welds, based on the probabilistic fracture mechanics, the likelihood of leak or rupture --

neither of which are linearly related to CDF and certainly not to LERF, right?

They didn't say anything about makeup capacity or any of that, or alternative ways to eject heat. That was unnecessary based on these particular calculations because they had a thorough enough basis without calculating all the way out to that. They just said we're going to stop where you're putting water on the floor, essentially, at an 80 percent through wall, so not even water on the floor, really.

MEMBER DIMITRIJEVIC: All right. Well, I understand. Thanks.

DR. RUDLAND: Yeah. That's the philosophy we take a lot of times with this probabilistic fracture mechanics is that, again, if the failure frequencies are, like I mentioned in my presentation, low enough, then there is absolutely no -- a strong impact on the plant risk. And so there's no reason to go through and run a complete PRA with a change of any type of initiating frequency or anything.

MEMBER DIMITRIJEVIC: I understand. So it's frequency of relief, basically, what you are calculating then. Okay.

DR. RUDLAND: Yeah. Probability -- the frequency of leak and/or the frequency of pipe rupture, right? Or rupture of the component that we're looking at in this particular case.

MEMBER DIMITRIJEVIC: Okay. Thanks.

MEMBER ROBERTS: Yeah. This is Tom. Just following up on Vesna's question. I had a similar question I wanted to ask. Slide 4 references the pressurized thermal shock report and talks about through wall crack relative to conservatively soon to be equivalent to an increase in CDF.

I pulled the report. It uses LERF, and what it says is basically that there is uncertainty in whether or not the event would cause some sort of, you know, beyond design basis event that would also cause a containment bypass. It considerably assumed it would cause a LERF.

And so we used 10 to the minus 6, which I believe is the Region II or small change definition for the reg guide, so those are just kind of the 10 to the minus 7, which would be the Region III, a very small change.

So it seems like the precedent was the small change relative to LERF. I just wanted to -- you know, it might be worth correcting the slide to say that -- Vesna, does that make sense? Because I don't think they are using CDF. I think it was LERF.

But I think they are also using 10 to the minus 7, even though it was LERF -- I'm sorry, 10 to the minus 6, even though it was LERF.

MR. DIJAMCO: Yeah. I might have to check that, Tom. But, yeah, thanks for that comment.

MEMBER HARRINGTON: This is Craig Harrington. You made the comment about activities in the code would be changed, but are you talking the 10 to 12-year thing or individual inspection?

MR. DIJAMCO: No. I'm talking --

DR. RUDLAND: Just inspection -- I'm sorry. Yes.

MEMBER PETTI: Sure. Go ahead, Dave. Yeah, go ahead.

DR. RUDLAND: I'm sorry.

MEMBER PETTI: No problem.

DR. RUDLAND: Individual inspection category intervals changing from 10 years to 30 years, or actually what it is is instead of taking an interval, they are using -- they are calling the term -- what's the term again?

MR. DIJAMCO: Authorize?

DR. RUDLAND: Deferral. That's right. They're deferring for 30 years. Instead of having one inspection every 10 years, they're deferring inspections for 30 years, as to the code cases that are going through code right now.

MEMBER HARRINGTON: So the issue in code of changing generically inspections or intervals from 10 to 12 years, how does that factor into all of this?

DR. RUDLAND: It complicates it.

MEMBER HARRINGTON: Well, yeah. That goes without saying.

DR. RUDLAND: And, again, I think like -- like Bob will have to take a look at that in his overall plan and change those -- for those plants that -- because, again, going from 10 to 12 is not a requirement. That's something they can choose to do or not. Right? So they have to determine which plants decide to change from 10 to a 12-year interval, and then propagate that through his little -- his little chart to understand that.

MEMBER HARRINGTON: So, at this point, that is not --

DR. RUDLAND: That's correct.

MEMBER HARRINGTON: -- a factor in this at all. It's a future --

DR. RUDLAND: And neither is the code stuff that I talked about. I brought that up just for information. It has not passed code, and we have definitely not approved that yet.

MEMBER HARRINGTON: Okay. Well, I think two of them have passed.

DR. RUDLAND: Have they passed, though?

(Simultaneous speaking.)

MR. GRIZZI: Yeah. There is discussion -- I'm sorry. This is Bob Grizzi with EPRI. To address Craig's question, and I think Dave sort of already did, but, yeah, that would be one of the triggers. You know, if you had -- you'll have to put some thought and logic into how many -- if they migrate to 12-year interval, you know, if it's one, it doesn't really have any influence. But if it's 10, then we have to look at it. Right?

And my gut says is that we're still going to be in a successful spot. It's just a matter of redistributing things. Go ahead.

CHAIR BALLINGER: Are those code cases available?

DR. RUDLAND: If they're published, yes.

CHAIR BALLINGER: Can we get the numbers to Chris? Dave?

MEMBER PETTI: Yes.

DR. RUDLAND: Yes.

MEMBER PETTI: This is Dave Petti.

DR. RUDLAND: Oh, I'm sorry.

MEMBER PETTI: Too many Daves.

(Laughter.)

MEMBER PETTI: I have this broader question, and it may require Dan or one of the PFM experts, Dave Rudland, to answer.

So in the PRA there are assumptions made on pipe breaks and even more scarce, like, a vessel break, and you -- you know, you roll that all up and you get a core damage frequency. PFM comes and you guys are evaluating everything to assure yourself that basically the stuff in the PRA doesn't change? That it's still a good representation of the risk profile of the plant when implementing PFM in, you know, regulatory decision-making?

Is that a fair way to think of it? Because it's certainly a sharper pencil. So is it just that we're getting smarter? Or if you actually did PFM, the core damage frequency might go down? I'm just trying to understand how it fits in the bigger picture.

DR. RUDLAND: So as part of example of piping and LOCA, for instance, you know, there are certain assumptions in all of the PRAs for small, medium, and large break LOCA failure frequencies, for initiating event frequencies for those -- for those types of access.

And so when we use these analyses, we usually compare our results to those type of initiating event frequencies. And, you know, in some cases like I mentioned for some of these operational experience analyses, we have actually been back to the PRA and included a change in the initiating event frequency to include the results that we calculate from PFM into those frequencies to see what the impacts are on the core damage.

Now, typically, if we can calculate, you know, an absolute initiating frequency that's lower than what's assumed in the PRA, then we can assume that the PRA is still bounding and appropriate. But if it's not, then additional analyses would be needed.

MEMBER KIRCHNER: Well, is that typically the case, then? This is Walt. Just to follow up on

MEMBER PETTI: Yeah. Which way does it go?

DR. RUDLAND: No. Typically, the probabilities that we'd get out of for -- for the passive component degradation that we know of right now is always extremely low, and there is always certain -- you know, certain bounding cases where you end up with higher -- at this point, through the analyses, of higher probabilities of failure.

MEMBER PETTI: So, in general, CDF is probably lower than what we -- what it's calculated to be in a PRA if one looks through the PFM lens.

MEMBER DIMITRIJEVIC: Dave?

DR. RUDLAND: Yes.

MEMBER DIMITRIJEVIC: If I can add, so pressure isn't that much -- you know, this is just one big event, and this is not going to impact the thing or that. When it comes to the LOCAs, this -- the pressurizer is internal. It will just add, you know, to the frequency of the piping breaks, right? But -- and these piping break frequencies are selected based on the expert opinions, because, you know, there is that -- you know, not the -- you know, there was no other reliable numbers to rely on.

But they are calculating here just leak, you know, so obviously break will be much lower frequency than 10 to the minus 6. So then you assume, if you have 1,000 welds in the piping, that will still be smaller than is assumed now. But I think that those events, like a small LOCA, have dominated like, you know, with a pressurizer, I mean, like what happened in Three Mile Island, you know, the pressurizer opening and things like that. We did not see too many, and everybody know the LOCA frequency -- large LOCA frequencies are very conservative. It generally takes time to change those things, so --

MEMBER KIRCHNER: Vesna, this is Walt.

DR. RUDLAND: Actually, whether it's --

(Simultaneous speaking.)

MEMBER KIRCHNER: What?

DR. RUDLAND: Go ahead, Walt.

MEMBER KIRCHNER: What's the nominal expert opinion on a large break LOCA for a PWR?

MEMBER DIMITRIJEVIC: Ten to minus six.

MEMBER KIRCHNER: Okay. Well, then perhaps looking ahead with PFM, one could -- could make a fairly good defense for a lower number.

MEMBER DIMITRIJEVIC: Yes. But, you know, well, I mean, in this moment, large LOCA is not the significant contributor to the risk. It could be influencing importance measures, you know, because of the, you know, human actions to switch --

MEMBER KIRCHNER: Right.

MEMBER DIMITRIJEVIC: -- and things like that. But it's a small LOCA which dominates, and that will be driven by the components, not the, you know, valve failure.

MEMBER KIRCHNER: Right. Right.

MEMBER DIMITRIJEVIC: And then, also, I mean, the NRC can look at that. Does it make sense to use that to change the --

MEMBER KIRCHNER: Well, the --

MEMBER DIMITRIJEVIC: You know, looking at the new plants, of course, you're not going to come with the vessel failure of, you know, 10 to minus 6. So, I mean, you know, it's -- you know, if you have, you know, still 10 to minus 9, then you will have really to sharpen the pencil. So --

DR. RUDLAND: I can't speak for all plant PRA, but our SPAR models I know have initiating event frequencies for large break LOCA that are -- that are bigger than 1E to the minus 6. I don't remember the number off the top of my head, but it's at least an order of magnitude bigger than that.

MR. WIDREVITZ: I think I want to emphasize, first of all, large break LOCAs are not the worst, as we just heard. Second --

MEMBER KIRCHNER: No. No. Did you have to look at --

DR. RUDLAND: -- you inevitably try to model the whole plant.

MEMBER KIRCHNER: -- whole spectrum of LOCAs.

DR. RUDLAND: Right. But the numbers we use are essentially events at site, right? So to try and go back and -- you know, earlier I was talking about first principles, digital twins, to go back to your whole plant and PFM the whole thing would be a budget that would make quite a lot of hearts sing, right? I mean, it's a tremendous piece of work, which is why we haven't done it.

We try to rely on sort of a plant level, site level estimate of the sort of size of breaks that may occur. And, of course, now you're starting to step into the fact that where the break occurs is the most important question, in addition to its size, right? Because some breaks are very flooding significant. That's a big deal. Some aren't.

And so there's a level of sophistication that PRA doesn't currently have. It's just -- it was not built into the PRAs, and it would be quite an undertaking to put that in. And so we're trying to stay below the level of that sort of analysis because it's really not -- it's not evident that there is a safety aspect to sharpening that pencil that far, right?

But in particular cases where we can, you know, really sharpen the pencil individually, there could be other benefits that applicants are trying to achieve and coming to the NRC to ask us to review.

MEMBER MARTIN: For perspective -- this is Bob Martin -- the 15-plus submittals related to PFM, they're all kind of same thing. Maybe you've released -

DR. RUDLAND: Yeah.

MEMBER MARTIN: Do you think --

DR. RUDLAND: Not at all.

MEMBER MARTIN: -- 55, all of them?

DR. RUDLAND: Mm-hmm.

MEMBER MARTIN: The reg guide of course lists a lot more than that, but there's one favorite, obviously, among the list there.

DR. RUDLAND: If I can add just one more comment about LOCA frequencies. You know, in the early 2000s, and in the late ‘90s, you know, the staff developed estimates of LOCA frequencies as a function of break size for at that time a voluntary rule to change the large break LOCA criteria.

And that's being -- that was never put into the regulations, but it's being revisited, and the staff has done a reevaluation of those LOCA frequencies to make it more modernized, and that's something that's going to be incorporated into the increased enrichment rule that you guys will be hearing about next month.

MEMBER KIRCHNER: I was asking a leading question, because that's where I was going. No. Exactly. I was --

DR. RUDLAND: And also, it has an impact on FFRD for the existing --

PARTICIPANT: That's exactly what we'll be talking about next month.

DR. RUDLAND: Okay. All right. Well, I'll wait then.

MEMBER KIRCHNER: If I could make -- while I have my mic open, may I make an observation? David, thank you for the nice presentation. I would just suggest that you change your title. I know what you mean. I think the people in the business know what you mean.

But if you just read it, on the surface it sounds like relaxing the code rules, and that's not really what you're doing. I mean, we are in much better shape in terms of plant inspections, technology to implement the inspections, experience with the inspections, all of which helps inform what you are presenting here.

So I think for the casual reader it sounds like relaxation to mean isn't the right word. You go on to say you're going to look at changing the interval of inspection, but the inspections probably have improved over time. They haven't relaxed. So just an observation of the optics of what's being presented here.

MR. DIJAMCO: Okay. Thank you for the comment.

CHAIR BALLINGER: Other questions before we switch over to Dan? Okay.

MR. WIDREVITZ: Good afternoon, everyone. My name is Dan Widrevitz, and I will be presenting the final presentation today with my colleague, Stephen Cumblidge, who has earned the honor of not being at the table.

We will be presenting on a materials risk guidance development effort that we call a risk-informed materials assessment project or RIMA.

CHAIR BALLINGER: Ah. I wondered what --

MR. WIDREVITZ: And now you know why there has been this little picture on every single slide.

CHAIR BALLINGER: Yes. We asked about that during break.

MR. WIDREVITZ: We are really excited that we made a logo that we kind of like so we put on everything.

You're going to see a couple familiar slides, not a coincidence. RIMA has been developing and seeding ideas back and forth with all of these ongoing reviews for a bit of time now, so you're going to see a little bit of replication here, and that's entirely correct.

Next slide, please.

While this is a short presentation, I did include a topic slide for a couple of reasons, but one which is it's nice to know what's coming, and the other is I want to make a little comment here about what's in the presentation. So the idea here is we're creating guidance for risk-informed decision-making for materials engineers and explain exactly what the purpose and applicability of this project is.

And, second, you'll see four of these bullets that are defense-in-depth, safety margin, risk impacts, and performance monitoring, which seem very familiar in today's discussion and they are also four of the five principles of risk-informed regulation. Not a coincidence. This is the -- this is the big deal.

Unfortunately, the fifth -- the fifth one, compliance with regulations, I feel is kind of self explanatory, so we won't be talking -- providing additional guidance on that within this project, because we think that one is pretty clear.

We'll also be presenting on a couple of what I think will be the more interesting bits here that we've generated for this guidance, what we're calling the tier list right now, and things that we're calling sampling considerations and sampling analysis.

So let's start demystifying all of these topics. Next slide, please.

The risk-informed materials assessment project is a risk-informed materials engineering forward guidance development project. The whole idea here is we have an awful lot of excellent guidance out there. It's all in my next paragraph that I'll be reading here in a second, and it's really written almost entirely in the language of the risk analyst.

That makes it a little more difficult to use for other specialties, both for applicants to understand, for reviewers to understand, and we really want to move it forward and make sure that we can translate into the materials engineering context, not create new policy, not make new ideas, translate, right, the well-established -- we've got our SECYs, we've got all kinds of reg guides and things out there, and really move it forward to make it more usable to the materials engineering community without quite as much time spent translating it into our domain.

This project is leveraging the processes and guidance of things like Reg Guide 1.174, Reg Guide 1.200, LIC-206, Reg Guide 1.245, et cetera, to enable more efficient and effect reviews. Ultimately, we want to provide the applicants and reviewers guidance in utilizing risk-informed decision-making for what we're calling non-integrated reviews. That is reviews where a materials engineer is essentially talking to a materials engineer and maybe you might be, you know, one reviewer, one sort of application kind of review as opposed to these integrated teams, we might see more sophisticated reviews.

Next slide, please.

What exactly is it? What is the set of applications that we're targeting this guidance for? We're targeting what LIC-206 calls Box 7 type applications. Since Box 7 is not especially descriptive, I'll explain exactly what that is.

LIC-206 is guidance on sort of integrated reviews and bringing more risk-informed decision making into NRR application reviews, and it describes the applications as coming in in sort of three bins, right?

So Box 6 is the bin of no probabilistic, risk, or PRA information used. That's sort of what we like to call traditional engineering regulatory decisions.

Box 8 is a fully risk-informed application following Reg Guide 1.174. It's very formal. It's got a risk analyst. It's got all of the other specialties that are involved. Where PRA is part of the basis for the regulatory decision, you must make a finding from PRA results. You have to review the quality of the PRA, et cetera. I always think of that as sort of the full faith review where you've gone all the way out through the PRA.

Box 7 is that midpoint, right, where there's probabilistic, risk, or PRA insights considered -- PFM, for example, right? Where the insights are used to determine scope and depth of review or reach or support regulatory findings, but you don't need to pull risk analysts in. You're not necessarily going all the way out to things like CDF and LERF because you don't need to to answer the important questions to make your findings.

And so that's where RIMA is focused. Why is RIMA focused this way? Why am I spending all of this time telling you exactly the size of my project? We were looking at the biggest problem that was worth solving that was small enough to still actually solve. Right?

So, you know, Revision 0 is -- you know, we've got to keep our ambition in a nice place. Revision -- we can push everything else that we want to Revision 1, but to get a Revision 0 you need to -- you need to target something that's worth doing. You know, it still has a chance at failure or it wouldn't be worth doing, but it's got a pretty good chance of success, too.

Next slide, please.

The staff has been generating what we call a preliminary set of RIMA concepts to support potential guidance document development. And we've essentially said to ourselves, can't we write something like a reg guide or an SRP section? Can we actually do it? Can we come up with something useful, what it is and what it will be, because obviously it does not fully exist yet.

We would like to get it out in public

about -- the second it's ready, and events keep overcoming our availabilities, but we're working on it. What it is and what it will be is clear, broader guidance in the language of materials engineers. There will be applicant guidance to enable high quality submittals and efficient staff review. And that is sort of the guiding light. If we're not achieving that, then we're not getting value out of the project.

What it is not and will not be is new policy on a staff member, not even a senior engineer. I'm not making any policy. That's not my job, right? It's not new policy, and it's not a deviation from Reg Guide 1.174, right? That's really the -- in my mind -- and this is speaking personally as Dan Widrevitz -- and 1.174 is a lot of the really good explanation of all of the concepts of this informed decision-making is one of the more thorough explanations.

I hesitate to say it, but I think it's true, is one of the shorter explanations out there. There are certainly a lot of interesting things like, how do you handle uncertainties in defense-in-depth? And I think 1.174 is a good place to start if you're wanting to learn about the concepts.

DR. BLEY: Dan? Dennis Bley.

MR. WIDREVITZ: Sure.

DR. BLEY: Are we going to be seeing a draft of that soon?

MR. WIDREVITZ: Well, I would have had a different answer before the ADVANCE Act. I've been spending 100 percent of my time on that for about a month and a half. So --

DR. BLEY: Your current answer is you don't know.

MR. WIDREVITZ: My current answer is we would like to bring it to the ACRS when we've got something we can show publicly.

DR. BLEY: It's big enough.

(Laughter.)

DR. RUDLAND: Yeah. We really kind of hope that we can get you our feedback, but also like public feedback. So we want to try to do it all at the same time and -- but we have to be mature enough of course, right? So we're working on that, and we have been kind of sharing these concepts with the industry as we've been developing them. So just to make sure that we're not going off in a completely wrong direction. So --

MR. WIDREVITZ: Yeah. One of our inspirations was the process where Reg Guide 1.245, the probabilistic fracture mechanics reg that was developed, and there was a lot of really good interaction with the public and with the ACRS. And we think that's a good model, something that could be as interesting as this.

So the answer is, yeah, we really want to get this out there, and it's a matter of finding the time on the schedule to work on things that are not immediate reviews and priorities.

So the following slides are going to detail what I call the preliminary concepts. I'll start. So, first, defense-in-depth. We want to further clarify the relationship between materials engineering topics and defense-in-depth considerations. Typically, materials engineering reviews do not establish defense-in-depth characterizations. We're not saying whether a system is being credited as defense-in-depth.

What we're doing is the materials engineering review supports that there is a commensurate level of assurance based on the characterization that it should be credited. The question we're answering: is the treatment of the subject systems commensurate with the defense-in-depth functions of the subject systems, right?

And so we're not saying, yes, no defense-in-depth. We're saying, yes, no credible, right? That's part of what we're supporting as a materials engineer.

Next slide, please.

The key consideration here is, is there enough assurance from the other four principles of RIDM to credit a subject system for defense-in-depth? I always like to include this diagram where I throw up the five principles of risk-informed decision-making to emphasize that certainly I understand, and I'm sure everybody who is -- who has spent time with it, these are mutually supporting principles.

They all rely on each other. They are more than the sum of the parts, right? And so we're providing the materials engineering understanding of some of those other principles to support the defense-in-depth needs of other folks at the NRC, for example.

Dave got really excited.

(Laughter.)

MR. WIDREVITZ: That's the next slide.

All right. So there will be some guidance on defense-in-depth. There will be further clarification of the relationship between materials engineering topics and safety margin considerations.

Here the key consideration is, are the safety margins large enough, in concept with the other principles, to manage uncertainties?

And we have a somewhat complicated diagram here, so let me unpack this, why we think this is an interesting diagram that's illustrating all of the various facets of material engineering support for safety margins.

So on the Y-axis we have something we're calling material reliability, considered sort of component integrity. How good is the component relative to the environment that it's operating in, the stresses it sees, right? At some point in that red section, you're in an operating condition where your component will fail. And in the uncolored section, you're operating with a component that remains intact, right? So you don't want to get to the red region of this plot no matter what.

The X-axis of this plot is time. Everything lives in time. As a materials engineer, aging is something we think a lot about. We've added a lot of extra here because there is a lot of places where the materials engineering supports that overall NRC mission.

So I'm going to start on the left. A

designer designs a component, and when he designs -- he/she/they design a component, they are designing it to have some sort of design margin, right? A safety factor built in. That design margin is meant to cover a whole bunch of uncertainties.

A lot of those uncertainties come into existence in design. You might not have an absolute perfect understanding --

(Audio interference.)

MR. WIDREVITZ: -- for example, right, but then you get a lot more uncertainties when you go to build your component. That's the next section here.

When you build your actual component, uncertainties like variability of materials, variability in welding processes, handling during installation, you start accruing more and more uncertainties. Depending on the level of your quality control, you are going to have some delta, and here we've made a nice little step, so it's easy to see. The diagram is slightly small. That stuff could be very small.

In a very high, strict quality control environment, it could be a little bit larger for, say, a commercial component. But there's going to be a little less actual margin in the component relative to design when you come into the real world, and that's understood. That's part of how you select the amount of design margin.

Materials engineers, right, we're doing part of the design review. We're doing some of the review about how you build, install, et cetera, components. When you get a component installed into service, it begins to age. It gets in contact with water, there's oxygen, people, you know, sometimes back up a backhoe against your pipe unexpectedly. Things happen, and the actual margin, the actual integrity, relative to whatever your failure zone is, will slowly begin to decrease. It will age.

You will manage this through a number of different kinds of programs, and what you're looking to understand is there's somewhere where you've decided -- and that's that red dashed line -- decided minimum allowed margin at this point, we've got to do something to bring that actual component back up to where we want it, to have that appropriate level of headroom between where a failure might occur and where the component is, right?

And so you're watching aging. You have aging management programs. You have performance monitoring. You have in-service inspection at all parts of this. And when it gets too low, you say, all right, it's time for repair, replacement, or some other mitigating strategy to bring that margin back up to where you want it for service.

And, again, materials engineers are heavily involved in that sort of thing, and so we're going to be covering all of that discussion in RIMA.

All right. Before I go further, do folks feel comfortable with that diagram? Does anyone have any questions? Because it does have a lot on it.

Okay. Seeing pleasant, smiling faces, let's continue.

The next portion of RIMA is clarification and discussion of risk insights derived from qualitative or non-PRA modeling. We've already had quite a discussion on probabilistic fracture mechanics, for example, and RIMA goes into that discussion of, what can you do with these sorts of things? And RIMA, you know, essentially ends at the point where you call a risk analyst, right?

So the reviews that we were talking about today, we are able to do that entirely with materials engineers. We didn't need to call the risk analyst. That's the space where RIMA really is, and that's an important part of understanding risk-informed decision making is knowing when to call it fracture, essentially. So that's something that's going to be covered in the guidance as well.

Ultimately, we want to expand on how insights are related through one or more elements of the risk triplet; that is, what can go wrong, how often, and what are the consequences, and how you could leverage that information.

Like Dave was saying, you know, PFM can give you some insights about initiating event frequency, right? That's how often are the risks triplet?

So it says more in a few slides, and the few slides are right now.

So PFM is often a risk impact insight in a risk triplet. Like I just said it's the how often. Frequently, it's giving you some more information, a sharper pencil than you had, and we can use this as an analogy to the frequency of potential initiating events, such as LOCA.

And if that number is nice and low, again, in days that I ran the number really low, right, that we don't need to go out and actually calculate all the way through the PRA to understand what we need to know about the risk impact of a particular application.

Next slide.

Performance monitoring. I admit this one is my favorite. We want to further clarify the relationship between materials engineering performance monitoring and the other principles of risk-informed decision-making, expand the discussion of performance monitoring and the bathtub curve relationship. Why am I bringing up the bathtub curve? It's not because we want applicants telling us where they think they are in a bathtub curve. It's because it's a very, very useful set of languages for us to come to a mutual understanding of the problem at hand.

And so we're certainly not trying to create a new bathtub curve-based piece of guidance, but we need to have words and bathtub curve has proven pretty useful.

Finally, there is -- sorry. One last thing. Dave would give this presentation much faster than me.

There is a discussion of the management of novel performance monitoring results. Something that has come up today is, at least in my mind, you don't want to be relying too much on ad hoc responses to novel results.

If you're really risk-informed, you want to have a good idea of, we had some sort of logic, we had a basis for making a decision, and what if that first automatic step of that decision logic isn't holding up? And when that step is automatic, you're going to get more reliable, more consistent results, and so we want to have some more guidance about what to do when these things show up.

You know, traditionally what happens is somebody picks up the phone and then you have a public meeting very, very rapidly, and we think we can do just a little bit more organized than that.

Next slide, please.

Dave earlier had his three bullet points describing exactly what performance monitoring is. When you're doing a review, what you're reviewing is what I call the several pillars. This isn't a special term I've suddenly come up with. This is just for the slide.

But when you're looking at a performance monitoring program, what are you looking at? You're looking at how much monitoring, what kind of monitoring, how often, and are there triggers for more or less monitoring with the program? That's how do you manage the data that is coming in essentially?

And the answers to these questions

obviously must be judged in the context of the other principles of risk informed decision-making, such as how does the subject system support defense-in-depth? If there is a system that is very important for defense-in-depth, the amount of performance monitoring and the nature is going to have to adjust the amount of weight being put on that system for the overall safety case of a site.

Next slide, please.

So I'm going to take a brief pause, and you can listen to my excellent colleague, Mr. Cumblidge, while he introduces the tier list. Mr. Cumblidge?

MR. CUMBLIDGE: Do I come up there?

MR. WIDREVITZ: Yes.

MR. CUMBLIDGE: Okay. So we're talking about -- I'm Stephen Cumblidge from the Piping and Head Penetration Branch. I'm going to talk how you -- the box for risk-informed, but you don't have a PRA or risk analyst involved. And also, how are you going to risk rank different systems in different parts of the power plant if you don't have a PRA specifically for that one?

Actually, the NRC is -- we've done a lot of PRAs in a lot of plants on a lot of systems. We have this data already. And so what we did is we took the SPAR-Dash data that we have -- and we have a huge database of systems, you know, and risks associated with each of these systems, and we kind of, you know, collated the data and put it all together and got kind of a simple first cut at what does this risk look like for the fleet and different power plants.

And also, as we looked through the SPAR-Dash tool, we thought that, okay, it looks better if you look at the individual systems. If you try and get too granular, it gets more challenging to get good results, especially for what we're trying to do. So we're really going to focus on broad systems and trying to go down to a component level.

Next slide, please?

So you take all of the data from the SPAR Dash pool for the fleet for the different systems. You put it together. What does it look like? Well, it looks like this.

So here you can see on the Y-axis we have the risk increase interval for the systems, and it goes from -- you know, up to 10 to the minus 1, means you're going to fail the plant if the system is on, if it's unsafe.

And we've got some -- the systems here,

we've got the, you know, log mean in the center, and then we have the -- one sigma standard deviation, you know, error bars or uncertainty bars here. And also, like, you've got a red line for 10 to the minus 2. That is, as risk increase interval is similar to conditional core damage probability, it's not the same. It's very similar.

So you've got, you know, 10 to the minus 2. That's very high. Ten to the minus 4, if you're above that, you're like, you know, got a red finding in theory, and also, if you're below 10 to the minus 4, that's analogous to something with a low safety significance under the EPRI categorizing things.

And, you know, there's another line for 10 to the minus 6. That is, basically, below that you're at a green finding, in other words analogous to a green finding.

So then we look at the data. What do we find? We find that, if you look at the systems, the reactor protection system is the most important system. That's not shocking. You can't shut the plant down. If there's something going wrong, you're -- it's not a good day. And that's pretty intuitive.

Now, the second most important system we found as far as, you know, the mean was the emergency feedwater system. I grew up in ASME Code space, you know, and doing inspections. Class 1 is the most important, Class 2 is second, and Class 3, and whatever, it goes -- diminishing importance.

To see a Class 2 system be one of the most important systems was -- you know, that's an important thing for the materials world to know is, you know, don't just focus on Class 1. These other -- these lower classes can be extremely important. So I think it was a very useful thing to get out of this information.

Yes. Go ahead.

MEMBER BIER: Quick question. The error bars are reflecting the variability from one plant to another. Is that correct?

MR. CUMBLIDGE: Yes. We took the fleet.

MEMBER BIER: Yeah.

MR. CUMBLIDGE: We took basically these systems for each -- for each plant that was modeled in the SPAR-Dash. As you can see, the scatter is very large in some of the systems.

MEMBER BIER: Yeah.

MR. CUMBLIDGE: So for some, you know, it can be extremely important and others not important from plant to plant, so -- which is one of the things

I was going to get to is the scatter is enormous from plant to plant, from system to system.

And so we're going to look at the -- and also, there's a log mean. This is not the mean, but the mean is the highest one divided -- the highest outlier divided by the number of plants.

MEMBER BIER: Sure. Yeah.

MR. CUMBLIDGE: So the log mean and the log -- and the standard deviation was -- it makes the easiest-to-read plot. You can also do high/low mean.

MEMBER BIER: Yeah.

MR. CUMBLIDGE: Or high/low median, or even -- but then all -- the trends are always the same, that this is the least confusing looking plot to get out of it.

MEMBER BIER: Okay. Well, thank you for the explanation. I think, you know, the big message of the variability, especially as you get away from the top two or three systems, is, yeah, maybe doing it based on a fleetwide average is better than not doing it at all, but not all that much has us go --

MR. CUMBLIDGE: But we have to recognize the usefulness and limitations of the list. And then we   this is a good -- I'm going to talk about the limitations of it later, and also the high variability from plant to plant is a very large part of that.

Then I guess other highlights I would say about this, and, you know, reactor cooling system, you know, basically, that's very high, as you'd expect.

Then service water, a Class 3 system, is on the same level as reactor coolant. Imagine, if you lose service water, you're not getting heat away from the core into the ultimate heat sink, that's -- you know, that's understandable, why service water is there, but -- and, again, the ASME Code space, where you determine what gets inspected and how often.

Class 3 systems are, you know, way down the list. This is the place where PRAs -- you know, the risk analysis is better than intuition and better than the ASME Code, quite honestly.

And then it goes down -- I'll get to the full list later.

So, looking at this, there is also emergency feedwater, auxiliary feedwater. That's PWR only. We recognize that. Also, some of these systems are, you know, different from sort of -- we saw something near the fleetwide one here, how does it break down between different designs and boiler and pressure?

Next slide, please.

And, you know, one thing we found when we did this is that if you divide between PWRs and BWRs, that's a meaningful difference. If you start breaking down the different types of PWRs and different types of BWRs, that was less meaningful.

So we'll skip -- we'll stick to Ps and Bs here. And we find, you know, PWR emergency feedwater -- again, the biggest system, and service water is, you know, third, and, you know, it goes down. Also, we find with the BWRs, the residual heat removal, which was -- that jumps up basically similar to emergency feedwater and risk, which fleetwide it was pushed down because, the Ps, it's not as important.

What we really wanted to -- we get some not so surprising and some very surprising results as far as, what is the very highest risk or lower risk? And I think this is -- it's a good way to ground yourself when you're coming into a review as to what are you getting yourself into? What -- again, I said it before, I'll say it again, growing up in ASME Code space, this is kind of stunning to see Class 2 and 3 systems this high up on the list.

And this is where, you know, risk informing is very important, and risk-informed thinking gets you out of more traditional thinking.

Next slide, please.

So we just kind of came up with this list, and I'll just say that we have tiers -- you know, Tier 3 reviews, like, you look at this, all of these systems are very important. You don't say oh, it's 2 to 3, we don't care. You say if it's Tier 3, that's the kind of normal review.

You would say these are the -- not the ones that are -- like Tier X, these are systems which you have to do extreme care if you're looking at a review involving this.

And so, you know, and, I mean, reactor protection is not a focus generally for materials, but for the upper head exams and for control rod drive mechanisms, anything involving those, that's -- we've been very involved with upper head exams for a long time. It somewhat justifies reactor coolant and reactor protection are both impacted by the upper head exams. So, yeah, it's --

MEMBER BIER: Can you go back to the previous picture for a while?

MR. CUMBLIDGE: Yes.

MEMBER BIER: Yeah. I want to take issue a little bit with the comment that, you know, yes, all of these are important. I mean, I'm not saying that because the risk increase is small, therefore, we don't care about materials.

But from a risk-informed perspective, I mean, let's say for BWRs there is really only two or three systems driving the risk informed discussion, and the rest, I mean, yeah, you want to be doing it just out of good housekeeping and all the other reasons, but, you know, it's not going to drive the risk in nearly the same way, because those are orders of magnitude on the left-hand side. So --

MR. CUMBLIDGE: That's one thing we're getting out of this is which are the ones to pay most attention to. Here we -- you know, maybe I -- I'm sorry.

Next slide, please.

Okay. So that huge -- the very large variability, this tier list is not useful for individual plant review. You can't go -- like if a licensee sends you something saying we are going to do something on this system, you can't go oh, well, that's Tier X, no. Like, no, who knows where it is on there.

So this is -- the tier list is not good for individual plant reviews, like this one. The PRA people get very upset when they see that I've done this to their data. Yes, you took our database and you took averages, but please don't even -- we can't do that. We see the error bars are like eight orders of magnitude. This doesn't work. We know that.

But if you're doing rulemaking, if you're doing topical report reviews, if you're doing, you know, ASME Code actions that do affect the entire fleet or all of these ROPs, it's a very good idea to have this knowledge that I've been on reviews where, like, oh, that's service water, who cares? No, that's service water, we care. Spend the extra time, do the extra work.

Or, like, emergency feedwater. We had someone who was going to change their treatment of emergency feedwater. We dug into the PRAs and kind of the actual component-by-component diagrams, like, then, before we were satisfied. And so we were showing extra care with the emergency feedwater than we would have had probably before, because it's a very high risk system.

So it's good for focusing attention. But, again, it cannot be used for individual reviews. It cannot be used to actually make a conclusion, but it can be used to inform the person who is making the conclusion as to what to pay attention to.

Also, and we're bringing in a lot of new staff now. We're hiring a lot of people, and these are people who didn't even grow up in ASME Code space. They're just new hires. Do we can start them off on the right foot with, you know, here are the important systems, here is why they're important, here is how they impact risk, and it's kind of the way to be risk informed without direct PRAs but kind of a new way of thinking of things.

Now, one thing which I will say, this does not consider internal flooding, which can dominate risk. And though I can't -- we're thinking about how to include internal flooding in this type of thing, because, again, I've been involved in reviews where someone will say there's a pipe here. It's Class 3. Do we care? What room is that in?

(Laughter.)

MR. CUMBLIDGE: If that pipe breaks, you might not get that water goes where you -- where it's supposed to go. But if that water goes where you really don't want it to go, so I can't, you know, work on trying to -- that might not be in Revision 0. That might be in Revision 1.

(Laughter.)

MR. CUMBLIDGE: That's another way, but --

so any questions about the tier list or thoughts before we move back to Dan?

MEMBER DIMITRIJEVIC: Well, I just want to add something for your information, actually, you know, because this -- the very similar work is done for risk informed, you know, the Section XI changing the EPRI methodology, and I don't know did that table relate to the core case, if it went into that.

But it shows because the EPRI methodology chose not to use the, you know, PRA results directly, but to rank the system based just on the common sense, like how often is the system challenged, how many backup systems are available, so there is a nice table there which will show the same results as PRA.

Then, also, the flooding was the part of this risk evaluation for this EPRI risk-informed Section XI method. So just to mention this.

MR. CUMBLIDGE: Oh, no. The risk -- the EPRI method I've been going through pretty extensively the past while. The internal flooding is one of the things that's inspiring me, because, you know, that can dominate.

I'm going to turn things back to Dan. Dan?

MR. WIDREVITZ: Continue with sampling

considerations. So, unfortunately, we're no longer in the space of PRA results, so this might be slightly less interesting.

We're producing an expanded discussion of performance monitoring, including the framework to help identify target concepts supporting optimization of performance monitoring. It includes a discussion of qualitative factors as well as an example of statistically driven sampling calculation. We will be leveraging the bathtub curve terminology to create common language for discussion.

Here what I want to emphasize is these are discussions that the NRC, industry, that folks have been having forever, right? And you're going to hear a lot of things in the next few slides that are going to sound a lot like engineering common sense, right?

What we're doing is we're getting them on paper. We're making them very clear, so that we can have those discussions a little more quickly and more efficiently. As soon as we agree where we are on these tables, then we can move on to the devil in the details, whereas we've had a lot of discussions where it takes a certain amount of time to sort of find that mutual language up front.

Next slide, please.

The following tables I'm going to be showing here are initial thoughts regarding the impact of various considerations on necessary sampling. This section is all qualitative. Where you see a checkmark it means that a consideration likely indicates a particular column applies. We want to see that addressed in any discussion.

Where you see an up arrow, it means the consideration should have increased emphasis relative to if it wasn't subject to that. Down arrow means a consideration had decreased emphasis. Depending on how good your TV screen is, some of these are black and some are gray. Black means, yes, that definitely applies. Gray means it may apply; in some situations, it may not.

Next slide, please.

The first table that we're generating is what I call the generic life-stage determination table. This is where you agree sort of where that discussion is. Obviously, the life stage of the component is going to change what statistical questions you want to be answering with your performance monitoring, so you want to find a way to agree where you are in that life stage, not that you're monitoring that at all times, but that when you do need to have that discussion you agree sort of what the context is.

This table will say things like, if you have a novel material, process, or design, or a novel repair, you're likely to be talking the language of the burden of the bathtub curve. Where it's a new component, there's a lot of learning, there's a lot of -- it's a horrible term -- infant mortality. The worst parts are dropping out the fastest, right?

But, you know, there's other situations. If you're just doing a repair, that might be a burn-in repair. It might be something mature. You might have a well-understood repair and well-understood components with a lot of operating experience, pre- and post-repairs, things like half-nozzle repairs. So you just discuss -- this would make more sense to discuss as burn-in maturity.

You will be in a situation and you'll have a plant, for example, where you've only done pre-service inspections, right? At which point you don't have a huge amount of operating experience for that individual site necessarily. It's more likely to be permanent. But if you've had pre-service examinations and more than one interval of in-service inspection, you might be in a situation where you're really talking about sort of a maturity kind of performance at a plant.

DR. BLEY: Dan, Dennis Bley. I'm thinking of some design certs we've looked at over the last 10 years, and in a few of those designs we've had some really novel components in them and structures in a couple of cases.

For the components, in any case, they really did extensive testing, so that you had a much better database, and probably those components were past that burn-in stage by the time the designs came to fruition. Now, the structures, surely not. They weren't there yet.

I'm wondering, well, are you going to tell us what you do with this? That's the next thing.

MR. WIDREVITZ: Yeah. And I think that gets to how novel is it really, right? If you have a really good testing program, how novel is it, really? And I think you can have a really good discussion there, that it isn't necessarily -- or some aspect of it isn't necessarily novel.

And this is why there are checkmarks. You have to talk about it. It doesn't necessarily mean that the NRC is putting you in that bin, but it's important to talk in that context.

DR. BLEY: The implication, at least to me, is in the burn-in stage, if it's real, probably you look a lot more often.

MR. WIDREVITZ: Yes. And that's -- and in the actual guidance, we're looking at, you know, each one of these rows has text associated with it. And here we're just -- right now we're just putting the concepts together and getting them out early.

DR. BLEY: I think this is really important to get people thinking about, because in some of the newer designs that we're starting to see come in we've pushed kind of hard on the fact that this is new and we really have to be careful and monitor maybe a lot more than you normally would.

And I'm not sure everybody understands that concept. Coming up with novel was --

MR. WIDREVITZ: I did already say performance monitoring is my thing, because --

(Laughter.)

MR. WIDREVITZ: -- all my children are equal, but some are direct measurements. But, no, thank you for that, but -- design review might be somewhat larger than the RIMA project, so --

(Laughter.)

MR. WIDREVITZ: The second table that

we've been looking at is what we call qualitative factors affecting sampling intensity table. Right? So, again, in that first table, we're talking about kind of what is the context of the conversation? Is the context more like a burn-in, something where we don't necessarily have a lot of -- a triplet of capacity or triple of capacity. We don't have the data yet. Right?

So you see part of the maturity period, wear-out are here, and now where we're linking these, too, is we're linking to them what I call component level sampling and population level sampling. And what that really is is what do I want to have statistical assurance for?

So if I want component level sampling assurance, I want to know that each well, that each vessel, that each -- whatever it is that the materials engineer is reviewing, I want to have a sense of its individual quality, its current state, its standard condition, for example. That's what component level sampling means is that I have some information on the individual component level.

Population level sampling is I can answer questions that a population -- that they are sufficiently similar that I can do sampling for the population, and I don't necessarily need to be sampling from each individual component. If you have component level sampling, kind of get population level sampling for free. Right?

And this is saying where are you leaning towards one or the other, depending on a variety of potential circumstances, through DAFTA curves, for example, is component safety-related, right? So there's more emphasis on a safety-significant or a safety-related component. Obviously, for a new design, I hope that those two terms will be coming closer together.

RISC-2 from 50.69, for example, is in this table. If something is consequence-significant, right, that's something that we historically had to -- had to consider. Our reactor vessels have a very high consequence significance. There's only one of them, for example.

When you're talking about reviewing an aging management program, that's all about, what are the questions you're asking? Are you getting the evidence to answer those questions appropriately to where the subject components are? That sort of thing.

So there's quite a lot of up arrows here and checkmarks. There are some down arrows as well, right? Is the system failure tolerant? I think before break that is something that we can understand later. I think that gives you a little more assurance without necessarily having component level sampling.

Low impact and other safety-significant systems, is it in a room that does not have other safety-significant systems, right? That's where that comes in.

Redundancy, isolability, again, these arrows are relative things. They're not absolutes. And so they're helping to provide that discussion, structure, and context to get people to the right level in a consistent way in managing whatever topics that they're talking about.

Next slide?

The final table here is qualitative factors affecting sampling due to emerging events. So you've already heard me, that I certainly believe that it's nice to have a little bit of an expectation, so that when things happen, you're not in an ad hoc emergency situation. Something we've learned is not conducive to the best quality decision-making always, whether that's haste makes waste or others that you can fill in through yourself.

You know, we have four columns right now.

We have component level sampling, population level sampling. We also have site sampling expansion and population sampling expansion. Right? Are we in a situation where we know something about an individual location where you have to understand more by gathering more data about that site? Right?

A good example here is the site-specific event or chemistry issue, right? If there is a particular chemistry issue at one site, and then we know it has not occurred at another site, there is no implications at a population level, but there certainly could be implications within that site at other locations where you found the indicator. And so, in that case, you'd want to obviously have a site sampling and expansion to get that sort of data.

You'll see other categories here, things of novel indications identified at a single site, right? You know, there is always that first one, and it's very unique and novel and will never happen again. What if there's a second? What if there's a third?

By the third, you know, you might be in the situation novel indications identified at multiple sites, where you're clearly going to want to be talking about expansion both at the individual site and at the population sampling of other sites as well.

DR. BLEY: I like what you're showing us. I'm sitting here thinking, though, some people are going to say, well, all of these things could be important. I need a formula or a tally sheet or something that gets me to how often I have to look -- how many samples I have to take, and it feels -- putting clarity to this, so people can really use it, is going to take a fair amount of effort. Is that coming on the next slide or is --

MR. WIDREVITZ: No. So that will be coming in the future, and also Rev 1. Absolutely. And one of the issues you very quickly find is that every situation has very unique characteristics. Right?

And so one of the reasons we can have risk informed ISI on piping systems is you have a lot of piping systems, you have a lot of information to do intelligence sampling. Can you intelligently sample reactor pressure vessels? Not in the context of an NRC regulation.

And so there are so many permutations that I don't think you're going to be seeing a formula, you know, a useful formula, certainly that is as broad as RIMA, but there are cases where you can then use RIMA to build those subcategories from it, and you can actually start somewhere from a good foundation and build up.

DR. BLEY: I look forward to seeing that, because I'm -- clearly, somebody who has to deal with this, if they've absorbed everything you have here, it colors their thinking and probably do a pretty good job.

But others are going to want a formulaic way to get through this in a hurry, and it's feeling complex.

DR. RUDLAND: I need to be clear, though, that, you know, is the staff -- it will probably not get down to the level of detail that you're talking about. We're hoping that this spurs the industry.

DR. BLEY: Well, that's what's great about it.

DR. RUDLAND: Yeah.

(Simultaneous speaking.)

DR. RUDLAND: Right, right. Maybe there's a way through a topical report they can -- they can do this kind of stuff fleetwide and not -- you know, and not do it on a onesie-twosie kind of thing.

DR. BLEY: Right.

DR. RUDLAND: So, yeah.

DR. BLEY: That's my worry. You've got a good --

(Simultaneous speaking.)

MR. WIDREVITZ: Yeah. And I'll just say, this happens, right, every year. Somebody somewhere is doing this, and right now it's completely -- you know, you have the conversation, the phone call, and it's folks in the room. Right? And so we're hoping to help those folks in the room have that conversation converge more quickly.

MEMBER BIER: One other point, which really is just for your consideration, there are some guidelines for root cause analysis, which is kind of closely related to what you're thinking about, looking at the distinction, extent of cause versus extent of condition. You know, if the cause is due to corrosion, you know, where else could you have corrosion, you know, that kind of thing.

And, you know, I can share a document at some point or whatever would be helpful. It's not a reason that you have to adopt that thinking, but, you know, might be relevant to what you're doing, so -- yeah.

MR. WIDREVITZ: Thanks.

MEMBER BIER: Okay?

MR. WIDREVITZ: Yeah. And, you know, we recognize that the spider is out all over, you know, LIC-504, right, for example. The spider is out into a lot of places, and in Rev 0 we're trying to take that first real stop.

People have been justifiably cautious, and we have to recognize there is good reasons that they've been cautious about writing things like this down, and whether what we're doing helps or hinders is something that we've got to consider.

And that's one of the reasons, honestly, it has taken the amount of time that it has as well is there's a lot of interested parties, there's a lot of political technology that has to be engaged as well for this sort of thing. But we hope we're finding things that will actually be useful.

Okay. Next slide?

So that's qualitative. Quantitative, love numbers; they don't love us, unfortunately. Quantitative sampling calculations can be derived from statistical calculations. And as we have discussed today quite a bit, for example, we use these statistical calculations to support our review of the PROMISE Code submittals that Dave not here presented to us in a very nice amount of detail.

I'm also going to refer you to, again, he had this as well as Dr. Rudland and I have a PVP paper describing exactly what we did in this particular case. You're going to see it from the slide here in a second.

I'm going to go back to -- those tables help you figure out what your statistical question is, and then you need to go find the appropriate math to answer it, and look at the same number of questions as statisticians who ask, of course, but pick your favorite and go from there.

Next slide, please.

Personally, my favorite statistician said well, if you want a really, really, really, really easy one that even you can do, binomial distribution is a good place to start. Binomial is very useful because, while it certainly has assumptions like all statistical questions do, if you're essentially doing a cheat hypothesis test, you have a null hypothesis, which is there is no active degradation in this particular location, say, this particular family of components.

What number of inspections do I need to continue confirming that that's true? Or if I have a -- if I have some level of counterevidence, what number of inspections do I need to conduct to have a reasonable chance of finding that counterevidence to confirm or deny my hypothesis, which is that it's just fatigue, for example, in the PROMISE Code.

And so binomial distribution is, you know, and successes is the number of -- I'm getting ahead of myself. It allows you to calculate chance of finding something in a certain incidence rate in a population, assuming that population is essentially infinite and has identical numbers that replacement -- that there is -- replacement is essentially irrelevant. Anything you pick will be a random choice from that.

And so binomial has all of these weights in it that you have to be careful with, but it's literally a function of Excel, which is convenient. And so if that's easy enough for you to answer the question you need to answer, it's really useful that way because it's an accessible -- it's a very accessible method. But, as always, be very careful about the assumptions that come with using that distribution.

Next slide, please.

Another familiar slide, if you just don't want to make assumptions, Monte Carlo. This is the simplest Monte Carlo that you could ever run, and then you can program in every little piece you want, and you can make this Monte Carlo infinitely complex to the extent that you have time and patience. And one of the nice things is you don't have to make the same kinds of assumptions that you do for a nice analytical solution because you're just brut forcing the entire question.

And so, in this particular case, binomial assumes an infinite population when you have small populations, right? If you have two of a component and you do two exams, Monte Carlo will tell you that is a great -- that is a very sensitive inspection plan. Binomial tells you it might be terrible, and that of course is ridiculous, right?

So there is -- there is places where you need to find the right solution for the right question, and Monte Carlo is of course very, very flexible and doesn't make assumptions in the ways that analytical solutions do.

Next slide, please.

So what RIMA wants to do is present all of these together and say that when you combine the insights from your sampling considerations, trying to pose the right question, right, with your sampling analysis trying to answer that question, is going to really help you produce high quality proposals in the performance monitoring space.

Next slide, please.

So, with that, we've reached our takeaway slide. The RIMA project aims to build forward from Reg Guide 1.174 and similar guidance and to do so in materials engineering-specific language to really increase that efficiency, that consistency, to put it closer to the sorts of things that we do as materials engineers, or remaining entirely within the policy and the spirit of NRC's risk-informed decision-making.

It's really focused on what we're calling non-integrated as just materials that you're reviewing only submittals, particularly for Revision 0. It has statements that say and here you have reached the end. You can call a risk analyst. And you enter an integrated team and there's plenty of guidance for that.

It will have guidance on all five principles. Spoiler alert. Compliance with regulations is compliance with regulations. So really not very difficult to explain that one. It's all going to be translated and extended in that materials engineering context to really help folks out.

The tier list and sampling considerations are providing an increase in domain-specific granularity of guidance, to really give people more common language, more of a footing, right? When you're trying to do something, it's good to have a few other people who have thought about it already talking to you in your head through this document, so that you can get there quicker and to a quicker quality level.

And, with that, that is the end of my data presentation.

MEMBER BIER: One other comment regarding the transition from binomial to do you want to do something more elaborate like simulation is that the real key is that binomial assumes kind of independent. And, you know, if the things really are kind of like random manufacturing flaws that just occur in X percent of cases, then fine.

But if it's because of temperature cycling or corrosion or poor maintenance, or whatever else, then you're going to violate the assumptions of the binomial. And so, you know, that guidance needs to be conveyed somehow. You know, how does somebody know if they're in that simulation?

MR. WIDREVITZ: And that -- in the particular situation we used it, right, very weak evidence is very strong. Right? So if we find any evidence of a new act of degradation mechanism in the PROMISE Code subject components, that changes everything we thought -- it could potentially change everything we thought from the entire basis of those approvals. And so any evidence puts us in the other situation.

DR. RUDLAND: It's also population limited, right? So if we have a limited population, it's gotten -- also, you can use other statistical approaches or something like --

MR. WIDREVITZ: It does turn out that 61 is pretty good for --

MEMBER BIER: Sure. I like your comment just now -- I hadn't really made that connection -- but that years ago I wrote a paper that I could again, you know, transmit through Chris. But that to have evidence of safety requires really a lot of experience. To have evidence of risk, like one data point is good enough to say we never thought this could happen. Apparently, we were wrong.

And, you know, maybe it doesn't happen very often, but we were wrong that it can't happen, and that can be proven with one data point. So --

MR. WIDREVITZ: Yeah. And that's really why we have Table 3, to sort of automate expansion, right, so that we don't say when this -- if this evidence is significant, I don't want you guys waiting. We need to get together and get on this immediately.

MEMBER BIER: Thank you.

MEMBER DIMITRIJEVIC: I have a question. What's your thinking about the -- these things would be applicable for advanced light water reactors?

MR. WIDREVITZ: So, at the moment, Revision 0, since there are none, doesn't apply to them. But, ultimately, it's the same logic, it's the same philosophy of why they're -- what is going to be very different is the level of risk associated with any individual component with exposure to coolant or fumes, depending on the design.

So advanced reactors -- I can just say, I'll push that through Revision 1 as well -- but this is not -- this guidance simply isn't I think going to be especially helpful to design review, ultimately, because in design review a lot of these designs are absolutely first of a kind.

Fundamentally, there is technologies that we've seen incidence built, but not of these specific designs. And so, you know, if every -- if every condition puts you in the left-hand column in my tables of burn-in, for example, then you're going to want to -- you're going to be driven to relatively robust in terms of frequency and number of inspections, for example, to establish that operating experience.

I think there will be a lot of strong analogies, right, to where we are in the operating fleet as things age and we learn about them. But in terms of design review, those sorts of questions, you're trying to establish what -- do we have confidence that we understand what the safety margin is? Do we have confidence that we understand which systems make sense as a combined group for defense-in-depth?

And RIMA is more focused on the situation of the operating fleet where we have a lot of information about that. So it really is not -- it's not -- you know, we're not trying to get into LMP's turf or DNRL folks from the materials engineering branches.

And so while I think there will be lots of really good analogies, and maybe I could hope that folks will read it and say boy, I sure want to steal a lot of that text. That's useful to me. We're simply not aiming to cover that many bases.

MR. CUMBLIDGE: This is Stephen Cumblidge. Just to mention for reactors there's the RIM program, which is Reliability Integrity Management Program, has a lot of these same ideas in it. And so we're kind of taking some ideas, you know, to target reliability and putting them into this.

CHAIR BALLINGER: When I first saw RIMA, I thought it was a misspelled version of RIM --

(Laughter.)

MEMBER HALNON: So the only thing that -- I mean, the whole afternoon that I wanted to kind of gauge was maintain our bias to look for problems, not look away from problems, so that we have -- and I didn't see that, and I would just caution you, as you go forward, as you relax or extend, or whatever word you want to use, that we continue to do our performance monitoring to look for problems and not to verify that everything is good. That's a valid point, but, really, we need to keep that bias and look at --

MR. WIDREVITZ: I appreciate that, and I promise -- I'm just one person, but one of the things we want to emphasize in RIMA is that you have to do all five principles, and here are concrete things that should be seen for each principle. Right?

And we don't want to -- and you need to

have a good reason not to talk about all of the principles, and a reason should be that they are in a very good place, if you don't need to talk about them for a particular application.

And, you know, the notion that -- that performance monitoring can be, for example, run to failure, some systems where that might be perfectly applicable, chances are the NRC shouldn't be regulating it.

So that's -- I take that as a caution well taken, and I make no promises, but it is certainly something that's on my mind.

DR. RUDLAND: Yeah. The backbone of everything that we've done here is to continue to keep our eyes open for new and novel issues that may come up. That really has been the backbone of what we want to make sure that we do when we start to utilize these advanced analytical tools to try to change, you know, rules and regulations.

MR. CUMBLIDGE: This is Stephen Cumblidge again. One of our inspirations -- in France, when they were looking for fatigue laws and they found they had a systemic issue, you have to do sampling, you have to keep looking, you have to -- you can't stop looking, because you don't know when they find -- when they found something unexpected.

MEMBER BIER: Yeah. Greg, your comment about you have to look for the problems, not the good performance, I had a student a few years ago before I retired, and every time we had some unexpected result he would immediately come to me with a reason why it might possibly be correct, and I was like, no, you first have to go through all of the reasons what -- you know, like all 20 reasons why it might be a mistake.

You know, if you've exhausted all of those, then you can say, you know what? It's probably okay, but --

CHAIR BALLINGER: One thing, I think what we have going for us here is that the industry and the technology, including non-light water reactors, I might add, is at a point where we need to be in a -- you need to be -- we need to be able to find the problem occurring before it gets too bad.

And I'm probably not using the right words. I'm saying, with piping --

PARTICIPANT: Find it before it finds you.

CHAIR BALLINGER: That's a good point. In other words, you've got a leak in the pipe. You're walking down the plant. You've got unidentified leakage limits. You've got -- you're got an ejection seat, if you will, because you may have blown the mission and you've got a leaky pipe, but you're finding it before that leaky pipe becomes problematic.

And that's the problem with non-light -- with the new type of reactors, finding the -- finding the problem before the consequences get too bad.

MR. WIDREVITZ: I'd like to expand on that. So in internet Dave's presentation, you saw he had three bullets of what performance monitoring is, Mr. Dijamco. And one of those bullets is it must be a timely method to detect novel degradation, right?

And if you look in the NRC guidance, it is not performance monitoring if it is only identifying the failure that is already too late. It is only performance monitoring if it has a reasonable lead time to a consequential issue. And that's something that is very much important to emphasize when reviewing whether something is genuinely acceptable as performance monitoring or not.

CHAIR BALLINGER: Questions from -- thank you -- from the presentation? Questions from the members, either in person or virtual?

Hearing none, we should go out for public comments in this case. So are there members of the public that would like to make a statement? If there are, can you state your name and then make your comment?

MS. ANDERSON: So Victoria Anderson from the Nuclear Energy Institute, and I think one thing we wanted to make sure we conveyed was that we do understand the importance of performance monitoring. It's important for continued performance monitoring. But performance monitoring does not have to mean inspections.

There are many other ways we can do performance monitoring, and I think that's something we need to continue working on with the staff, because, you know, right now, with what we talked about today, every form of performance monitoring that was accepted is a kind of inspection, and that simply doesn't have to be the case.

And if we stick ourselves to inspections, we incur unnecessary costs. We take a plant's focus off the most safety-significant things. We potentially expose people to radiation when we don't have to. There are all sorts of issues with forcing inspection to be the only form of performance monitoring. So that's something we'll be continuing to work on in the future.

CHAIR BALLINGER: Thank you.

Other members of the public that would like to make a comment?

Hearing none -- oh, Tom Bosso.

MR. BOSSO: Yeah. Hi. This is Tom Bosso from the Nuclear Energy Institute. Just one thing, you know, towards the end of the discussion today, we talked about making sure that we detect -- we detect, you know, certain or new kind of degradation methods, and I'm concerned that we're not emphasizing the NEI 03-08 program, which was developed for that.

Now, the research, that's done both by the NRC and by EPRI. The degradation matrix that's maintained, the operating experience that's tracked, I mean, that was all developed for trying to -- for detecting any novel kind of -- novel kind of degradation.

So I'm just concerned that we kind of didn't even bring that up when these issues were brought up, and that this RIMA process doesn't do that. It really is -- and it was agreement between NEI and the NRC that the 03-08 program and those programs associated with that was really done for that. I mean, we are doing all kinds of research, and we do react on any kind of OE to make sure that we understand it or that it's tracked and it's, you know, looked for other applications of it.

So I just wanted to reemphasize that -- that we don't -- we don't miss that that's an important program. Thanks.

CHAIR BALLINGER: Now, is there anybody else that I've missed?

MR. O'REGAN: Hi. This is Pat O'Regan, a member of the public. Just a quick question. The RIMA stuff and the basis for the RIMA stuff, is that going to be made public?

CHAIR BALLINGER: The way these meetings are organized, we accept comments from members of the public. If you want a specific question answered, please send a note by email to Chris Brown, who is our Designated Federal Officer, and he will get back to you with an answer.

MR. O'REGAN: Thanks.

CHAIR BALLINGER: Okay. Maybe three times is the charm.

Okay. Since we're not -- this is an information meeting. There is no issues. We're not having a discussion whether we have a letter or anything like that, but it's very informative. I'm sure I think I speak for the rest of the Committee --

Subcommittee.

So thank you very much for, in your case, spending eight hours with us today, and the rest of the staff, and the rest of you folks.

So absent any other issue that I've overlooked or forgotten, this meeting is adjourned.

(Whereupon, the above entitled matter went off the record at 4:58 p.m.)

Use of Probabilistic Fracture Mechanics

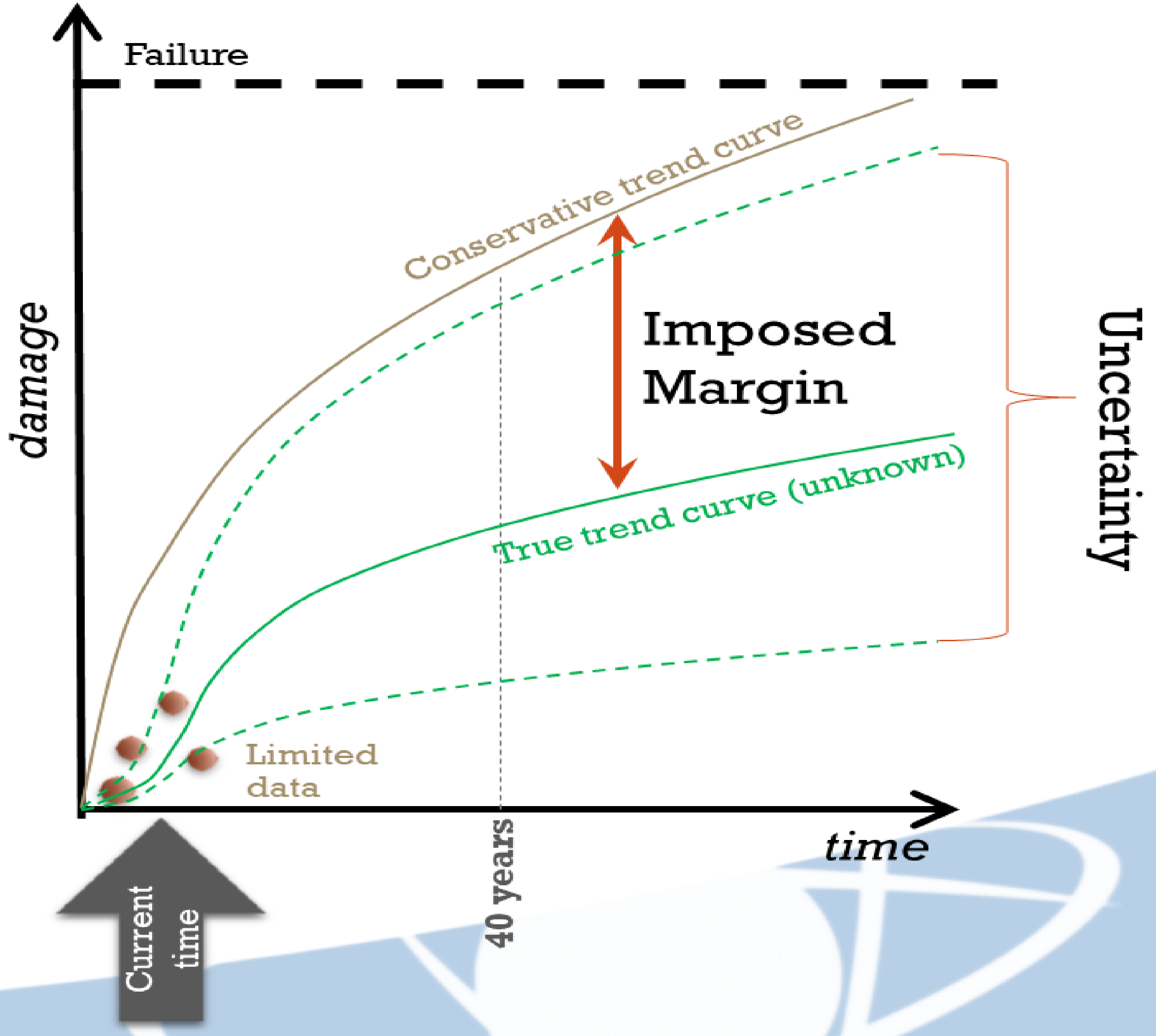
Remarks by

David L. Rudland, Ph.D.
Senior Level Advisor for Materials
Division of New and Renewed Licenses
Office of Nuclear Reactor Regulations

Advisory Committee on Reactor Safeguards
Meeting of the Subcommittee on Fuels, Materials, & Structures
November 21, 2024

Motivation for Probabilistic Analyses

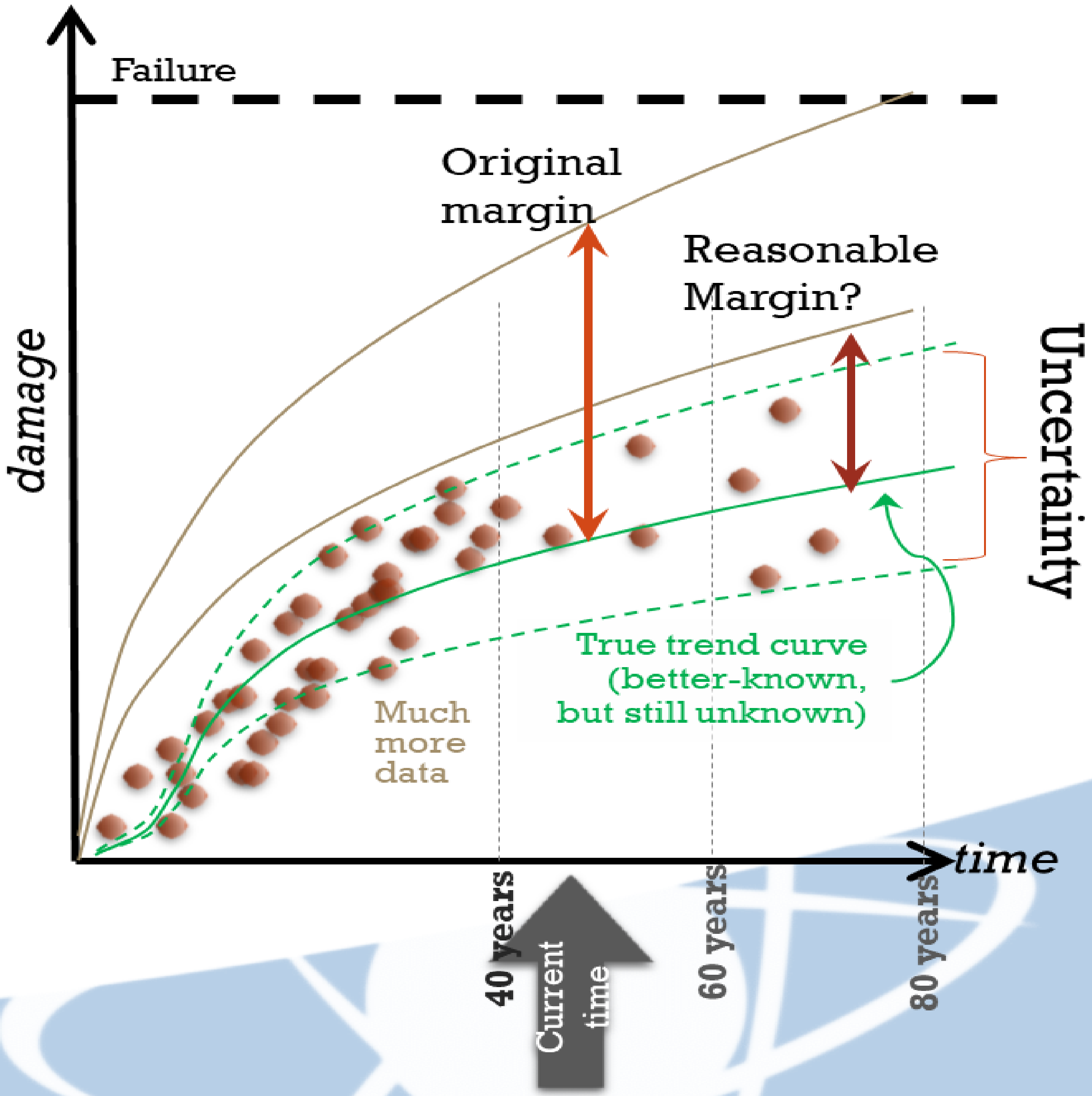
- **Early in Life**
  - Limited data – large uncertainty
  - Every discipline gets its own margin
    - Loading over-estimated
    - Material resistance under-estimated
  - Conservatism does not limit operability
    - Plants are new
    - No plant near failure



Motivation for Probabilistic Analyses

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

- **Later in Life**
  - More data & knowledge support improved models – less uncertainty
  - Original margin overly burdensome? Do we change the margin with time?
  - Issues
    - Deterministic margins make all inputs conservative
    - Deterministic approaches
      - Not well suited to quantifying actual risk
  - Solution: Probabilistic analyses –
    - Properly account for true uncertainty

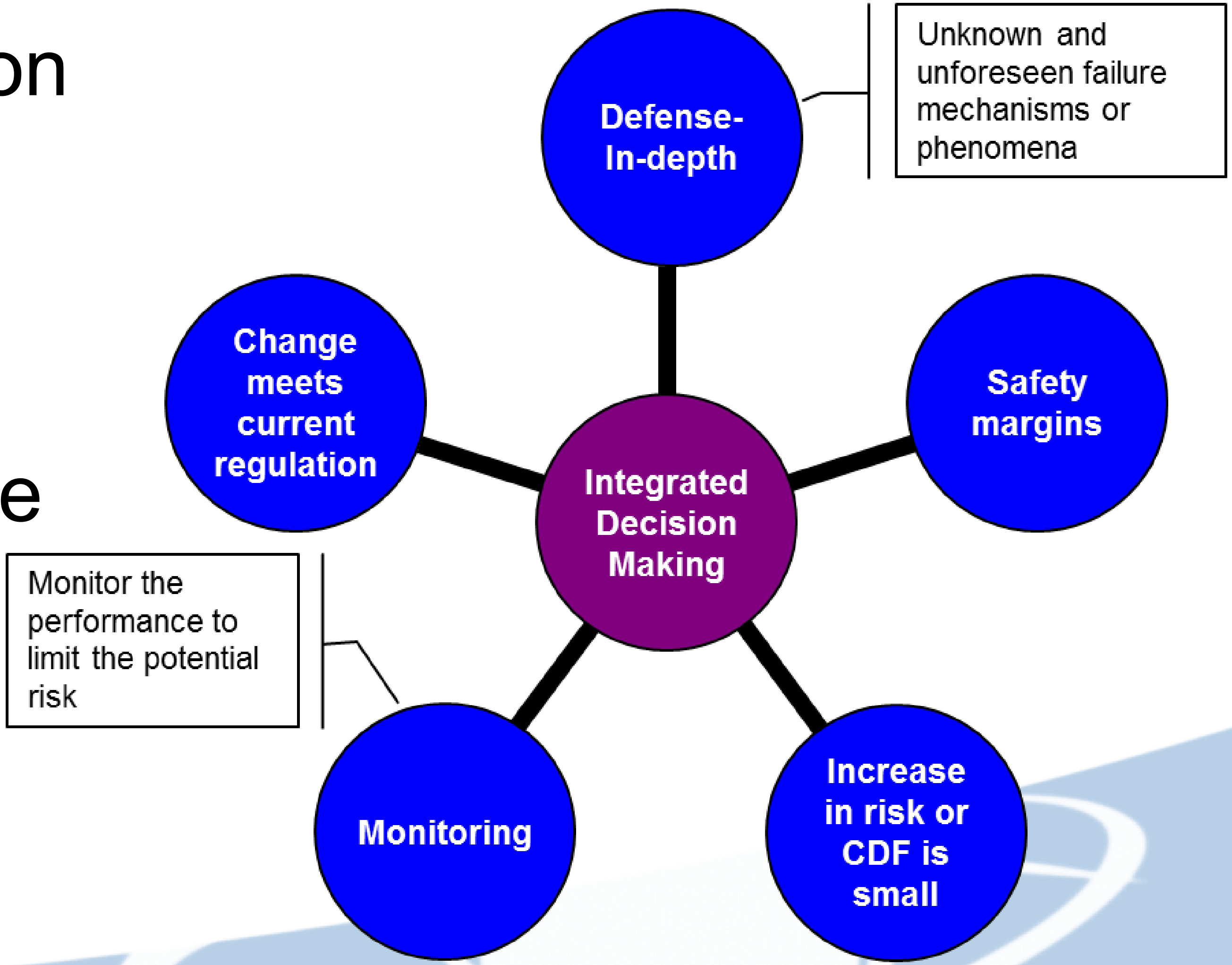


RIMA

Integrated Decision Making

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

- Objective is integrated decision making
- Key is risk informed not risk based
- Use of risk insights for passive component integrity

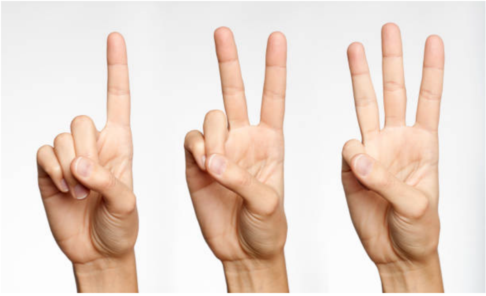


If CDF is invoked, RG 1.174 submittal may be needed

Probabilistic Fracture Mechanics

Probabilistic Fracture Mechanics (PFM) brings together information from the risk-triplet,

What can happen?



How often?

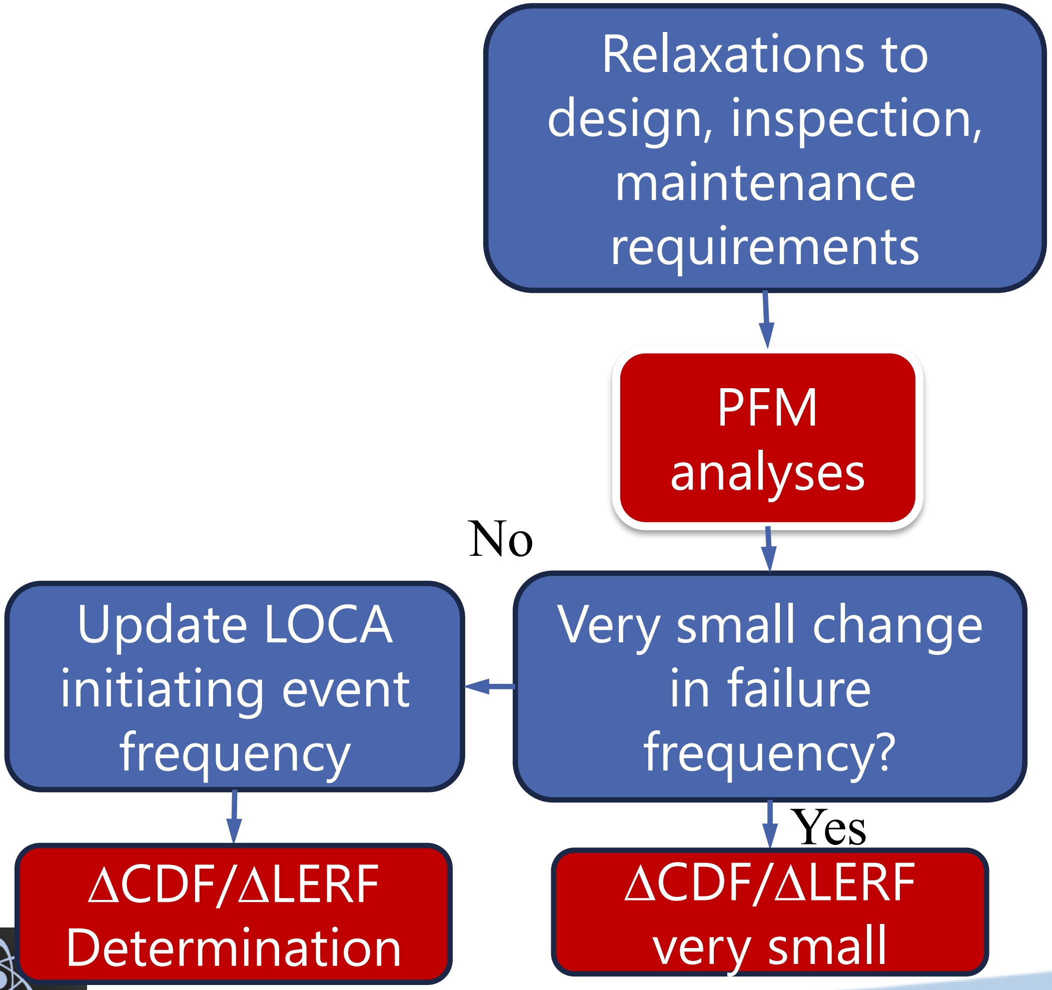
What are the consequences?

For example, PFM can be used to estimate the probability of leakage or rupture of a pressure-boundary component

The outcome of PFM is inherently a risk-insight

U.S. NRC recognizes PFM as a leading technique for managing risk-informed management of long-lived passive components

PFM is only one Part of Risk-informed Decision Making



If CDF is invoked, RG 1.174 submittal may be needed

Piping and Vessel PFM Codes

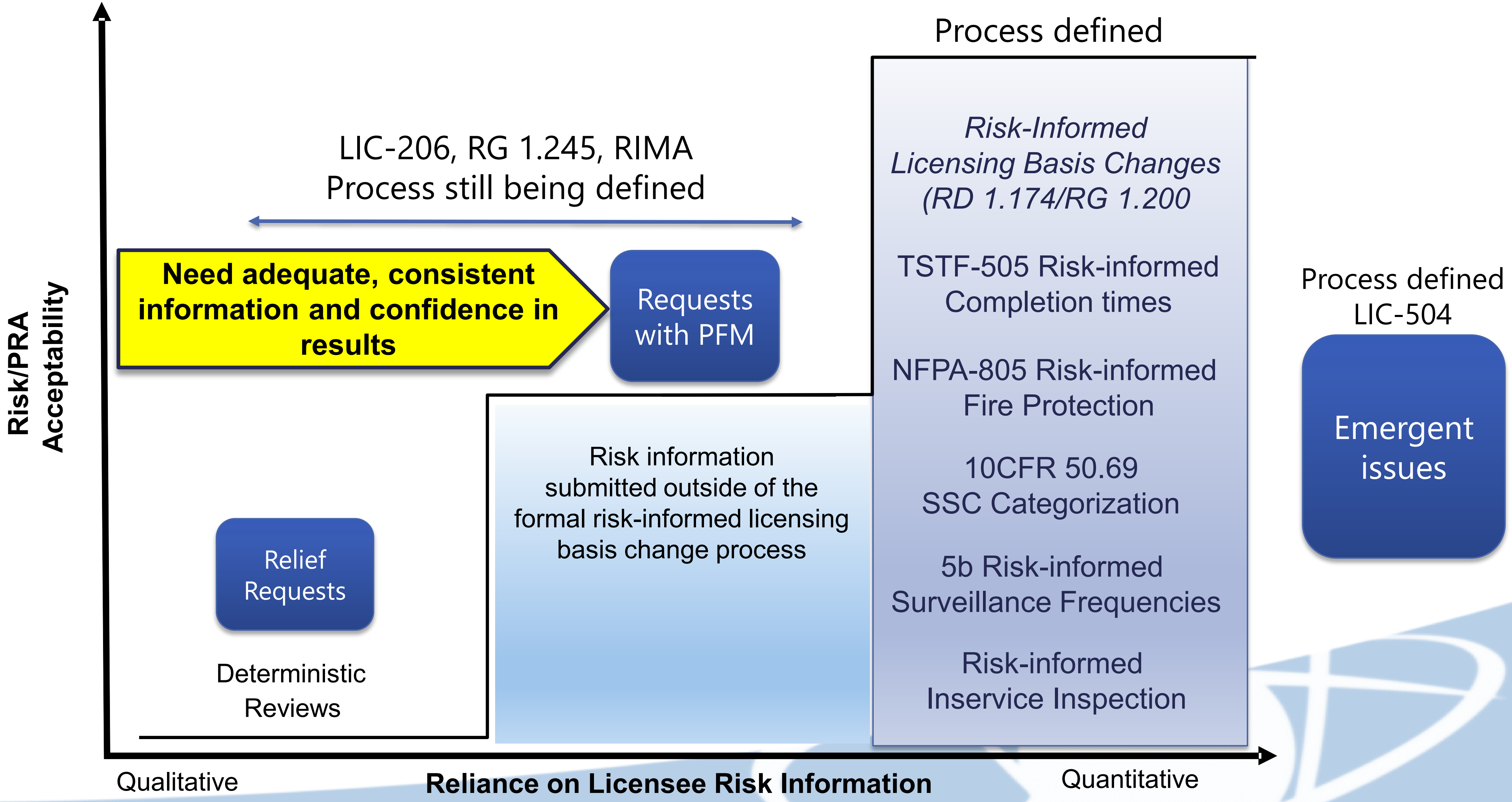
Not exhaustive list

	Past 1980-2000	Present 2000-2020	Future 2020 - ?
Piping	Praise, PROST, NURBIT, PRODICAL	PRO-LOCA, xLPR V2, SRRA, WIN-Praise, PASCAL-SP, Prometheus	xLPR V3+, Problem specific
Vessel	VISA, VIPER	FAVOR, VIPERNOZ, PASCAL	FAVPRO, Problem specific

Problem specific: PROMISE, PIPER-CASS, others

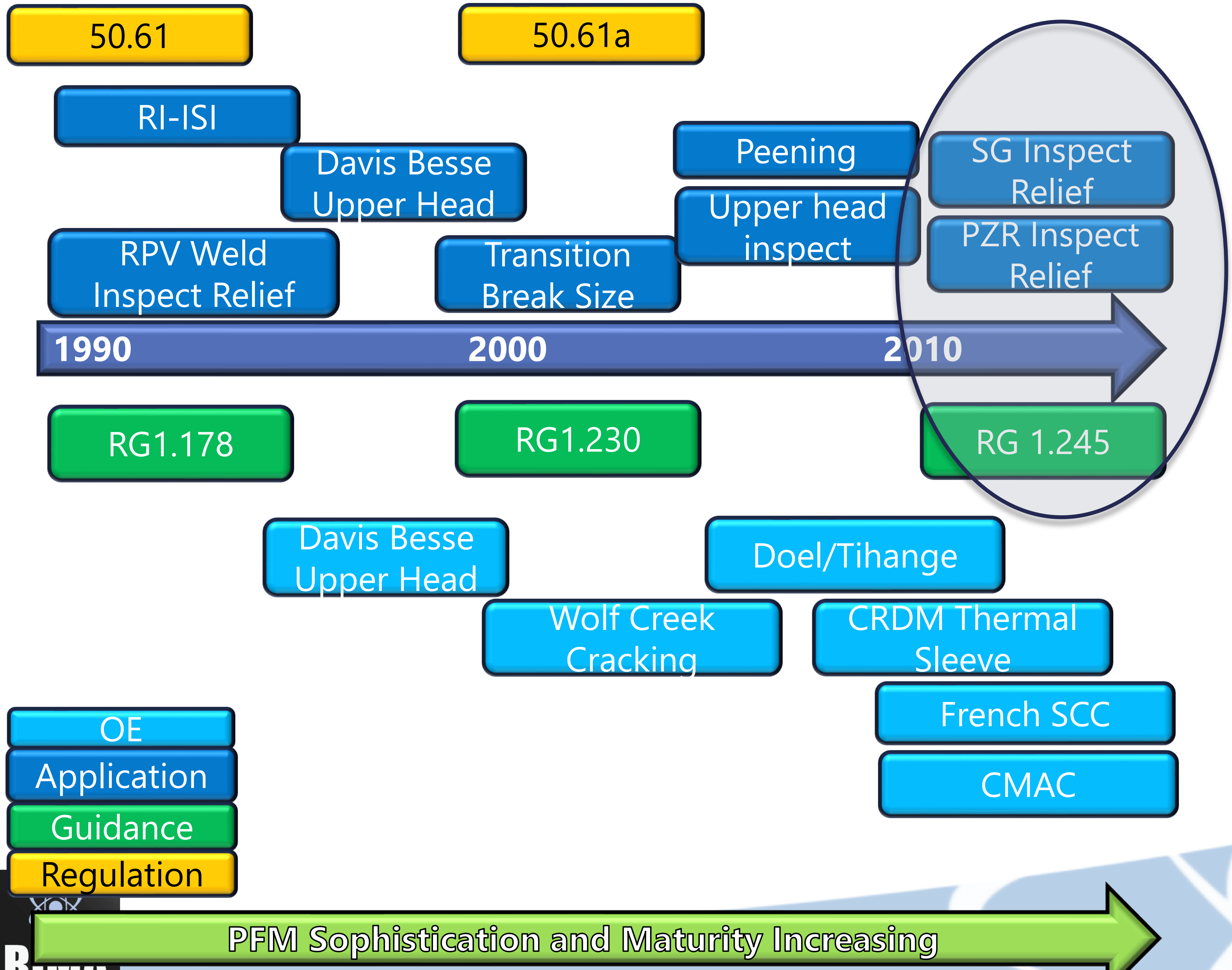
NRC developed | Industry developed | Joint developed | International

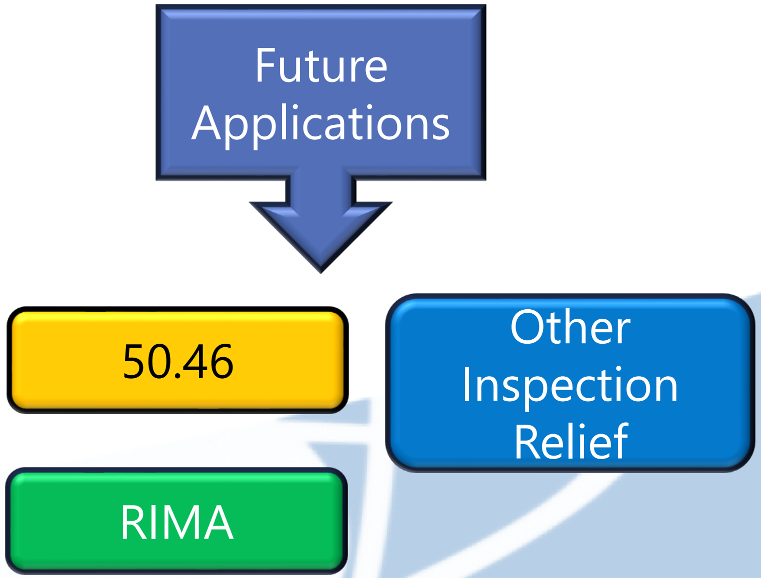
Licensing Reviews and Emergent Issues



Timeline of PFM Applications

Not exhaustive list





Bases for Past Success

- Computer code bases were technically adequate (V&V)
- RG 1.174 process was followed, or probabilities were very small – performance monitoring was sufficient
- In many cases, deterministic and probabilistic analyses were used
- Sensitivity/uncertainty analyses used to demonstrate impact of important variables

Past challenges in Piping and Vessels Probabilistic Integrity Analyses

- Incomplete uncertainty characterization
- Code and basis not submitted for review
- Incomplete code technical basis and/or V&V
- Ignored tenants of risk-informed decision making – performance monitoring
- Acceptance criteria
- Guidance being (or has been) developed to address challenges

Summary

- U.S. NRC recognizes PFM as a leading technique for managing risk-informed management of long-lived passive components

- PFM, used with or without PRA, can be a useful tool in optimizing inspection as long as other risk-informed principles are considered

- NRC continues to develop guidance to address PFM challenges

ASME Code Inspection Relaxations

Applications and Performance Monitoring

DAVID DIJAMCO

PRESENTATION TO THE ACRS FUELS, MATERIALS, & STRUCTURES SUBCOMMITTEE

NOVEMBER 21, 2024

Topics

- PFM aspects staff focused on
  - PFM acceptance criteria
  - Audit of the PROMISE PFM computer code
  - Sensitivity studies
  - Criteria for plant-specific applications

- Performance monitoring
  - Statistically determined inspection sample size

- Plant-specific applications
  - Pressurizer (PZR) and steam generator (SG) vessel welds and nozzles
  - Single/two-unit plant submittals and fleet submittals

Precedents for PFM with adequate performance monitoring (vessels)

- Elimination of BWR vessel circumferential weld examinations
  - PFM → BWRVIP-05 and BWRVIP-329-A (based on FAVOR analyses)
  - Performance monitoring → axial/longitudinal welds still being examined
- 20-year ISI extension of PWR vessel weld examinations
  - PFM → WCAP-16168-A (based on FAVOR analyses)
  - Performance monitoring → coordinated fleet inspections that ensure regular stream of monitoring data
- Reduction of BWR vessel nozzle inspections (Code Case N-702-1)
  - PFM → BWRVIP-108 and BWRVIP-241 (based on VIPERNOZ)
  - Performance monitoring → 25% of nozzles still being inspected

PFM aspects staff focused on

Acceptance criteria

- 1×10^{-6} failures/yr, consistent with the basis during the development of 10 CFR 50.61a, in which reactor pressure vessel (RPV) TWCF was conservatively assumed to be equivalent to an increase in CDF.
  - Conservative because in reality an increase in RPV TWCF does not mean an equivalent increase in CDF
  - Details are in NUREG-1806, “Technical Basis for Revision of the Pressurized Thermal Shock (PTS) Screening Limit in the PTS Rule (10 CFR 50.61)”
  - Used for the PFM analyses in:
    - EPRI reports 3002014590, 3002015906 for SGs
    - EPRI report 3002015905 for PZR
  - While PZRs and SGs are safety significant, they are not as safety significant as the RPV; therefore, staff finds 1×10^{-6} failures/yr appropriate.

PFM aspects staff focused on

Audit of the PROMISE computer code

- PROMISE stands for **Pr**obabilistic **O**pti**m**ization of **I**n**s**p**e**ction
- 2.5-day audit (ML20258A002); objective was for staff to understand how PFM principles were being applied, were they consistent with guidance
- Referred to RG 1.245 (guidance for PFM submittals)
  - Inputs/models (probabilistic models, e.g., mean and standard deviation of distributed variables, but also non-probabilistic models, e.g., FEA, stress intensity factor solutions, ISI & exam coverage)
  - Uncertainties
  - Convergence
  - Software V&V
  - Sensitivity studies

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PFM aspects staff focused on

Audit of the PROMISE computer code (continued)

Key observations

- Software V&V was adequate
- Uncertainties adequately addressed
- Initial flaw distribution model was adequate
- ISI and examination coverage adequately modeled
- Performed adequate sensitivity studies

RIMA

PFM aspects staff focused on

PROMISE audit – V&V and Uncertainties

- Software V&V
  - Followed ASME NQA standards and 10 CFR 50 Appendix B guidance
  - Software V&V plan and V&V reports generated
    - Plan contained testing of the various parts of the software, and that testing results were adequate and reflected in the reports

- Uncertainties
  - Mean and standard deviation values of random variables (i.e., those with a probability distribution rather than a single value) were consistent with previously accepted values.

crack depth	crack length
fracture toughness	crack growth rate
crack growth threshold	

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PROMISE audit – Initial Flaw Distribution, ISI & Exam Coverage

- Based on the Pressure Vessel Research User's Facility (PVRUF) unused RPV
  - Developed from NDE of fabrication flaws in the vessel weld
  - Consists primarily of small-surface breaking flaws
  - Used in the BWRVIP-05-based submittals

- Staff ensured that ISI and examination coverage (of the weld volume) were modeled since these are key aspects of ASME Code, Section XI, examinations.
  - ISI model: implemented through a probability of detection (POD) curve at times of inspections
  - Examination coverage model: implemented by allowing modeled postulated flaw to grow for a number of realizations proportional to coverage missed

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PROMISE audit - Sensitivity studies

From RG 1.245:

2.11. Sensitivity Studies

In most cases, the applicant should perform sensitivity studies to understand how analysis assumptions impact the results of the overall analysis, to show why some assumptions may or may not impact the results, and to understand new and complex codes, models, or phenomena, especially if there are large perceived uncharacterized uncertainties. The applicant should assess its PFM software and analysis to determine the sensitivity studies category shown in Table C-10. The applicant should follow the guidelines in Table C-10 to document the details of sensitivity studies. If the combination of PFM software and analysis belongs to category SS-1 in Table C-10, the staff does not recommend performing sensitivity studies.

Staff ensured that sensitivity studies (SS) were performed for the critical parameters of stress and fracture toughness.

- SS on stress up to more than 2 times base case stress levels, and on fracture toughness up less than half of base case fracture toughness were performed and showed that acceptance criteria of $1x10^{-6}$ failures/yr was met.

PFM aspects staff focused on

Criteria for plant-specific applications

- EPRI reports were based representative/conservative geometric configurations, transients/cycles based on survey of PWRs

- Thus, the need for criteria for the following parameters in plant-specific applications:
  - Geometry
  - Materials
  - Loading conditions (thus stress) and cycles

PFM aspects staff focused on

Criteria for plant-specific applications (continued)

SGs

EPRI Report 3002014590

EPRI Report 3002015906

PZRs

EPRI Report 3002015905

Staff also evaluates plant-specific inspection history: number of ISIs and examination volume coverage.

Performance monitoring

Supports RIDM in three primary ways

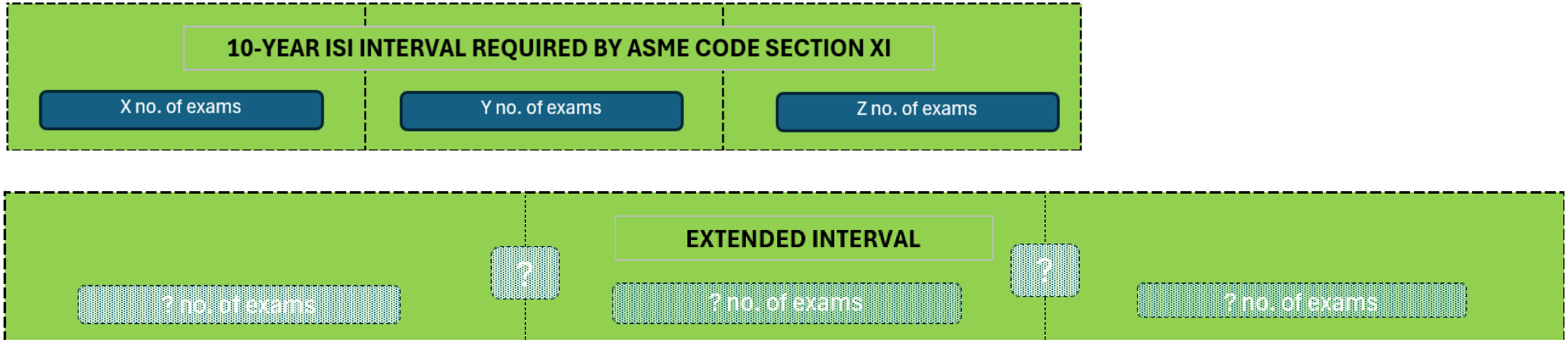
- Direct evidence of presence and/or extent of degradation
- Validation/confirmation of continued adequacy of analyses
- Timely method to detect novel/unexpected degradation

What about the other 3 aspects of RIDM: safety margins, defense-in-depth, and compliance with regulations?

- Safety margins and defense-in-depth: primarily have to do with design; design parameters (material properties and operating characteristics) and multiple means to accomplish safety functions are not changing
- Compliance with regulations: licensees seek an alternative to ASME Code requirements pursuant to 10 CFR 50.55a(z)(1)—evaluated by staff

Performance monitoring (continued)

Illustration of interval extension



- Performance monitoring is built into the ASME Code Section XI ISI interval.
- Fewer inspections with interval extension. The question is: what inspection sample size is acceptable?

Performance monitoring (continued)

Statistically determined sample

- Quantitative sampling calculation can be derived from statistical calculation (next two slides)
  - Binomial distribution
  - Monte carlo analysis

- At the conceptual level, the objective is to determine the sample size (in our case # of inspections) from a population of like objects that gives x% probability of “success” outcome (detection of degradation/cracking), assuming a certain p% of the population has characteristic for "success" outcome (degraded/cracked).

- Staff described details in *Rudland, David L. and Widrevitz, Dan,* ***PVP2023-105203****, “Statistical Approach to Developing a Performance Monitoring Program”*

Performance monitoring (continued)

Binomial distribution

- The binomial distribution is frequently used to model the number of successes in a sample of size "n" drawn with replacement from a population of a certain size
- Can be used to find # of inspections needed to find a crack
- Independent of population size

$$f(k,n,p) = \binom{n}{k} p^k (1-p)^{n-k}$$

$$\binom{n}{k} = \frac{n!}{k!\,(n-k)!}$$

k= number of successes (cracks found)
n=number of trials (inspections)
p= probability of success on an individual trial (% of population cracked)
If k=0 then this is the probability of no successes is:

$$f(n,p) = (1-p)^n$$

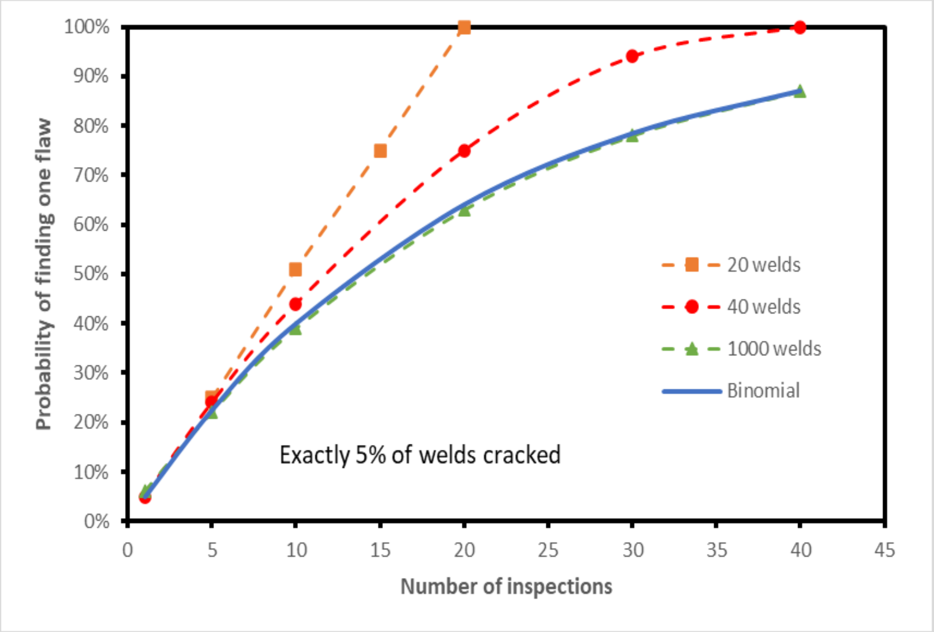
and therefore, the probability of at least one success is:

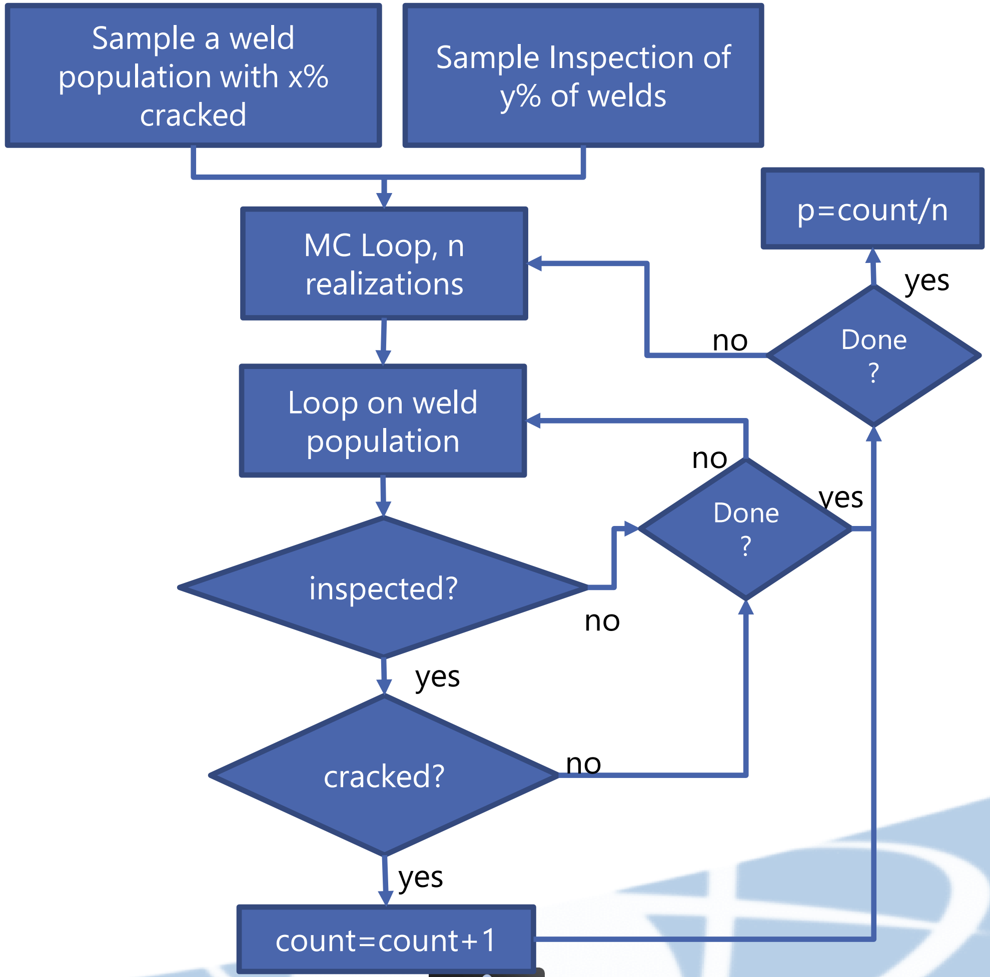
$$1 - f(n,p)$$

Performance monitoring (continued)

Monte carlo (MC) analysis

- Same concept can be applied with an MC analysis
- More general, allows maximum flexibility in the analysis
- Binomial response can be recreated
- Works for better for small populations

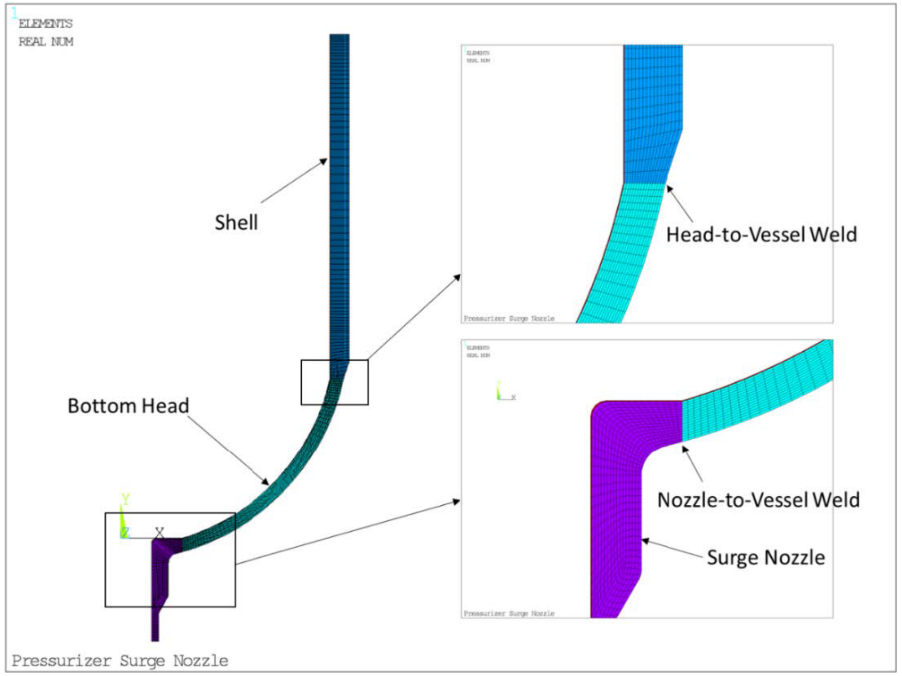


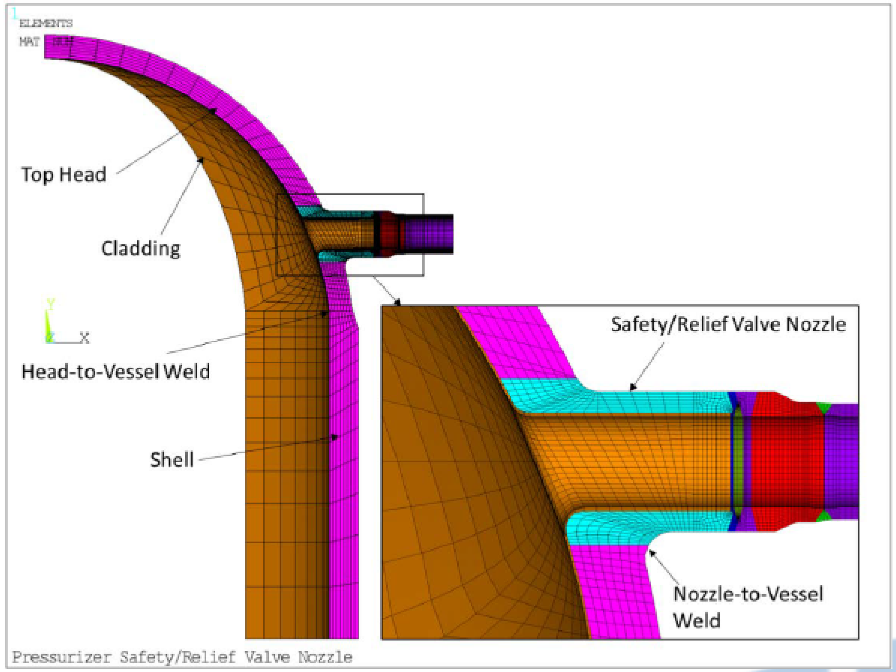


Performance monitoring (continued)

Should the statistics be applied at weld level or whole component level?

Weld level



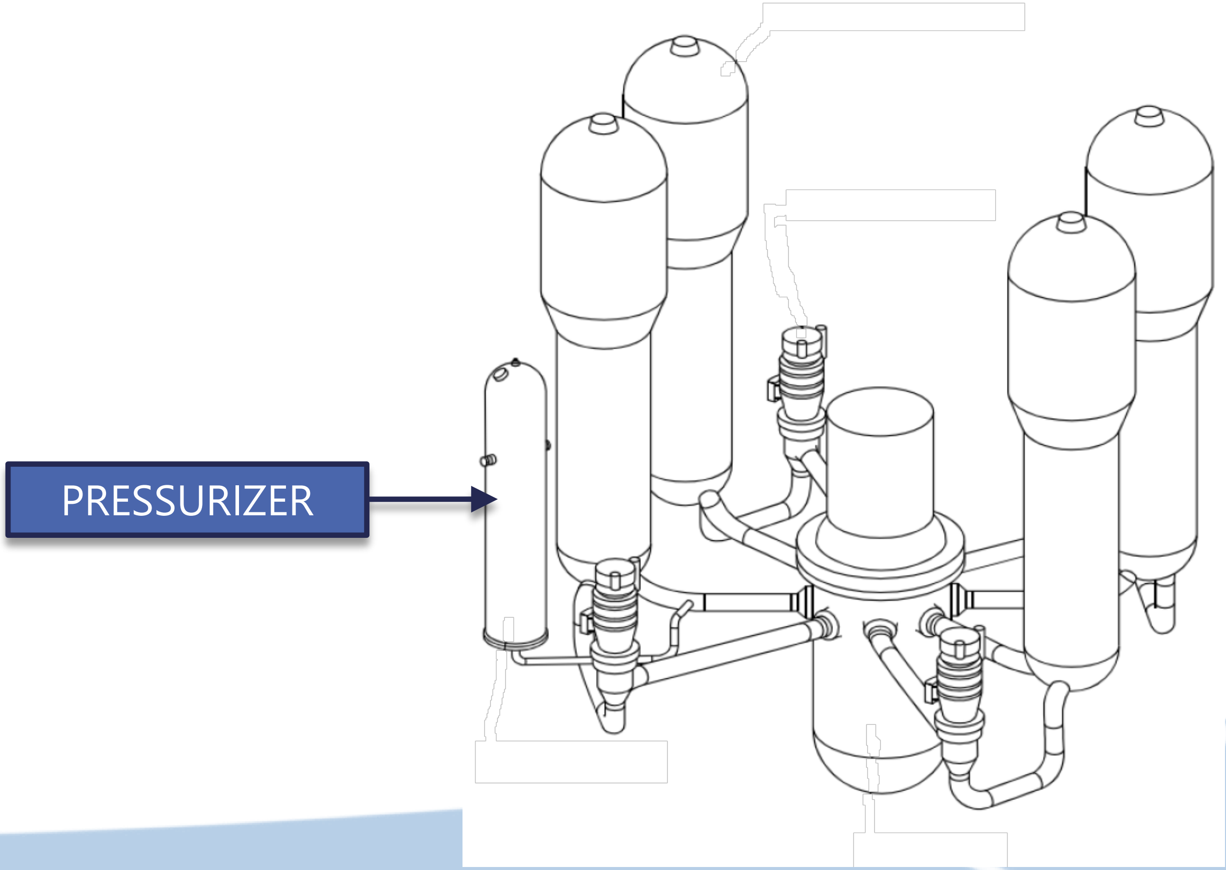


RIMA

Performance monitoring (continued)

Should the statistics be applied at weld level or whole component level?

Component level: inspection of the whole component means inspecting the suite of welds required to be inspected for that component (PZR in our example).



Performance monitoring (continued)

Example of statistical calculation for PZRs (1 of 2)

Objective:

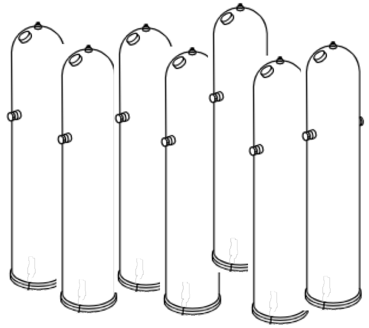
Determine inspection sample size for performance monitoring of PZRs

Population size = 61 PZRs (61 PWRs in US, one PZR ea)

5% of population is degraded/cracked

90% probability of detecting at least one crack in the population

→ BINOMIAL/MONTE CARLO



→ **25%** of population of PZRs

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Performance monitoring (continued)

Example of statistical calculation for PZRs (2 of 2)

- Submittal with 1 unit requesting three 10-year intervals
  - 3 PZR inspections required by ASME Code
  - 25% sample = 1 PZR for performance monitoring sample (rounded up)

- Submittal with 10 units requesting three 10-year intervals
  - 30 PZR inspections required by ASME Code
  - 25% sample = 8 PZRs for performance monitoring sample (rounded up)

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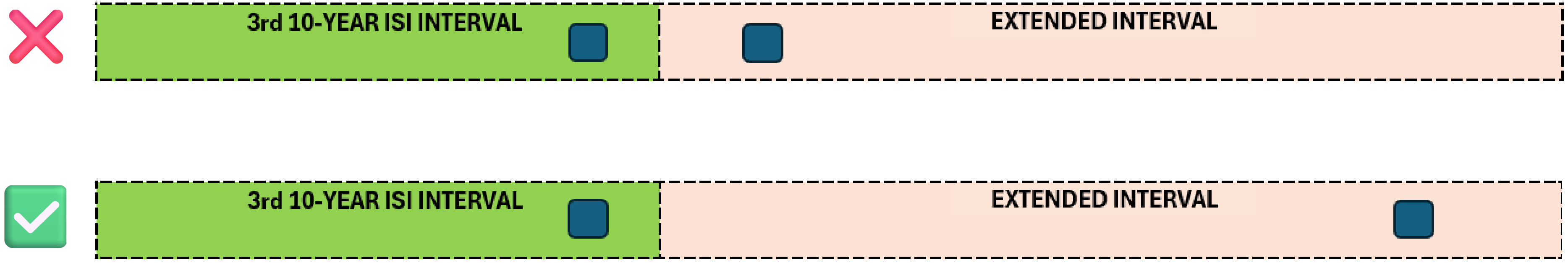
Performance monitoring (continued)

Timing of inspections



- Inspections performed later during the requested extended interval more impactful (but time from last inspection can't be too long).
- Later inspections have more chance of detecting degradation (if present) than earlier inspections since the degradation has had time to develop to a level that is detectable.

RIMA

Plant-specific applications

Submittals using the EPRI reports as technical basis

- Applications (i.e., submittals) have been coming pursuant to 10 CFR 50.55a(z)(1) requesting to extend ISI intervals, referring to the EPRI reports as technical basis.

- Staff approach on evaluating these:
  - PFM consistent with the technical basis reports, especially that the submittal meets the plant-specific criteria covered earlier
    - EPRI reports 3002014590 and 3002015906 for SGs
    - EPRI report 3002015905 for PZRs
  - Performance monitoring is adequate

Plant-specific applications (continued)

Single or two-unit plant submittals

- These submittals are for one or two-unit plants proposing to extend the ASME Code required 10-year ISI interval to up to three 10-year ISI intervals.
- They refer to the EPRI reports for the PFM the technical basis and provide an adequate performance monitoring plan.

Plant-specific applications (continued)

Fleet submittals

- These submittals are for more multiple plants (thus for multiple units) proposing to extend the ASME Code required 10-year ISI interval to up to three 10-year ISI intervals; tech basis for PFM also the EPRI reports.

- Proposed performance monitoring gets interesting since now you have different alignment of ISI intervals of the various plants.

Plant-specific applications (continued)

Fleet submittals

Plant \ Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
V 1	3rd Interval			4th Interval								4th Interval		5th Interval				X[1]							6th Interval - ASME Code PZR Requirements Resume							12/5/2043			
V 2	3rd Interval			4th Interval								4th Interval				5th Interval							X[1]		6th Interval - ASME Code PZR Requirements Resume							12/5/2043			
W 2	5th Interval											6th Interval							7/31/2030																
X 1	4th Interval									5th Interval										X[1]	6th Interval									6/12/2041					
X 2	3rd Interval		4th Interval										5th Interval								X[1]			6th Interval								3/3/2043			
y 1, 2, 3	4th Interval		5th Interval										6th Interval									#													
Z 1	3rd Interval					4th Interval						4th Interval					5th Interval			X			X				6th Interval - ASME Code PZR Requirements Resume								10/24/2046

LEGEND	
(green)	Inspection Interval prior to Alternative RA-22-0257
X	Scheduled Performance Monitoring Exam
(orange)	Deferral Period per RA-22-0257
(light blue)	Subsequent Inspection Interval: Reverts Back to ASME Code Requirements
(red)	Current License Period End Date
#	[redacted] Current License Period End Date: Unit 1 - 2/6/2033; Unit 2 - 10/6/2033; Unit 3 - 7/19/2034

Proposed Performance Monitoring Sample

Plant-specific applications (continued)

Fleet submittals

Calculation of total ASME Code required PZR inspections

Site	# of units	# of ISI intervals	ASME Code Required PZRs = units × intervals
[redacted]	2	2	4
	2	2	4
	1	2	2
	3	1	3
	1	1	1
Total			14

Using statistics, sample size needed is 0.25 x 14 = 4 PZRs (rounded up)

Calculation of PZR equivalents

Unit	# of Section XI exams	# of performance monitoring exams	PZR Equivalents = PM exams / required exams
[redacted] 1	10	2	0.2
2	10	2	0.2
1	10	2	0.2
2	10	2	0.2
	10	2	0.2
Total			1.0

Total no. of PZRs in proposed monitoring sample is = 1.0 (from above) + 3 (from prev slide) = 4

Example of how the staff confirms that the proposed sample size for performance monitoring is adequate.

Guidance?

- There have been fifteen or so submittals for PZRs and SGs since the first submittals.
- Similar approach taken for other components. Examples:
  - Heat exchanger vessels
  - Reactor closure head studs, but with DFM as technical basis instead of PFM
- These clearly bring up the question, is the staff developing guidance?

Questions?

Optimization of Select NDE Examination Requirements

Robert Grizzi, Program Manager
EPRI - Plant Support / NDE

ACRS Meeting
Rockville, MD
November 21, 2024

Background - Problem Statement

There are many examinations being performed that are **perceived** to have **low value** based on a history of **few or no relevant indications** being identified during routine inspections **on prescribed intervals.**

When were these intervals established?

- Generally, 40+ years ago during the construction and early operation era

Who established these intervals?

- Codes and Standards organizations

How were these intervals established?

- Engineering judgment
- No supporting technical bases were developed

Background - Impetus

- EPRI led, industry member focus group (circa 2017)
- Focus Group
  - Established metrics
  - Deliberated and selected examinations of interest

Metrics Used to Prioritize Examinations – Value

Item	Metric (unit)	Point Value Assigned		
		15	4	1
1	Perceived Value of The Exam *Considerations: probability of finding flaws, component criticality, reactor type applicability, NSSS design applicability* (Qualitative – *Subjective*)	Low	Med	Hi

Metrics Used to Prioritize Examinations-Impact

Item	Metric (unit)	Point Value Assigned		
		1	2	3
2	Impact to Critical Path (hours)	≤ 2	>2 and ≤ 12	> 12
3	Expected Accumulated Dose (mrem)	≤ 100	>100 and ≤ 1000	>1000

- <u>EPRI Report 3002012965:</u> *Identification and Assessment of Low-Value NDE examinations with High Outage Impacts (LVHOI)*
  - Surveyed utility members, ranked and prioritized results
  - 34 individual ASME Section XI Code-required examinations

Scope of Components - PWR & BWR Designs

- Accessible Areas of Reactor Vessel Interior (Visual Examination, ASME Item B-N-1)
- Reactor Vessel Studs
- Non-Reactor Vessel Pressure-Retaining Bolting (< 2" / 51 mm in diameter)
- PWR Steam Generator Feedwater and Main Steam Nozzle-to-Shell Welds and Nozzle Inside Radius Sections
- PWR Steam Generator Auxiliary Feedwater Nozzle-to-Shell Welds and Nozzle Inside Radius Sections
- PWR Steam Generator Primary Nozzle-to-Shell and Pressure Vessel Welds
- PWR Pressurizer Nozzle-to-Shell and Pressure Vessel Welds
- BWR Class 2 Heat Exchanger Nozzle-to-Shell Welds; Nozzle Inside Radius Sections; and Vessel Welds

Objective

Optimize component examination requirements using:

- Historical operating experience,
- Historical inspection data and results,
- Fundamental engineering methods,
- Modern day analysis tools to develop robust and comprehensive technical bases, and
- All without any adverse impact to the safe and reliable operation of nuclear facilities

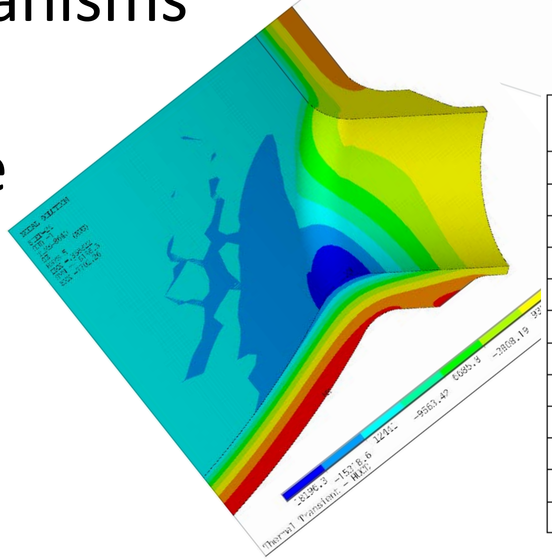
Steam Generator & Pressurizer Examinations (thru 2019)

- Steam Generators
  - 2,101 examinations performed based on survey responses (some did not respond)
  - 3 indications reported
    - 1 linear indication was reported on the OD of a nozzle to shell weld, found by magnetic particle inspection. It was dispositioned with light grinding/blending to acceptable standards
    - 2 exceeded ASME Section XI acceptance criteria but were determined to be fabrication (not service induced) flaws. They were evaluated and found to be acceptable without repair
- Pressurizers
  - 1,162 examinations performed based on survey responses (some did not respond)
  - 4 indications reported (all from a 2 unit, single site plant)
    - Flaw evaluations were performed to show acceptability of these indications, and follow-on examinations showed no change in flaw sizes since the original inspections

3,263 Reported Examinations, No Unacceptable Indications

Technical Bases Overview

- Introduction
- Review of Previous Related Work
- Review of Inspection History and Examination Effectiveness
- Survey of Components and Selection of Representative Components for Analysis
- Material Properties, Operating Loads, and Transients
- Evaluation of Potential Degradation Mechanisms
- Component Stress Analysis
- Probabilistic and/or Deterministic Fracture Mechanics Evaluation
- Plant Specific Applicability
- Summary and Conclusions



Sensitivity Study Variable	Importance Factor (%) for Probability of Leakage
Fatigue Crack Growth Rate Coefficient	87.82
Crack Length	9.39
Crack Depth	0.00
Fatigue Crack Growth Rate Threshold	0.01
Fracture Toughness	0.01
Crack Face Pressure	0.04
Pressure	1.82
Residual Stress	0.00
Heat-Up/Cooldown	0.01
Loss of Load	0.04
Load Increase (5%)	0.69
Load Decrease (5%)	0.16

Generalized Conclusions

- ✓ Analyses showed success in **considering 80 years of operation**
- ✓ Results are **acceptable relative to safety margins** (probability of leak or rupture < $1x10^{-6}$ failures per reactor year of operation)
- ✓ Results **support mitigation of personnel health and safety risks** through reduction of unnecessary inspections
- ✓ Results **promote ALARA** through reduction of unnecessary inspections
- ✓ Results allow **resources and schedule to be focused on higher priority** outage activities

Technical bases support optimizing examination intervals out to 30 years

Results (1/2)

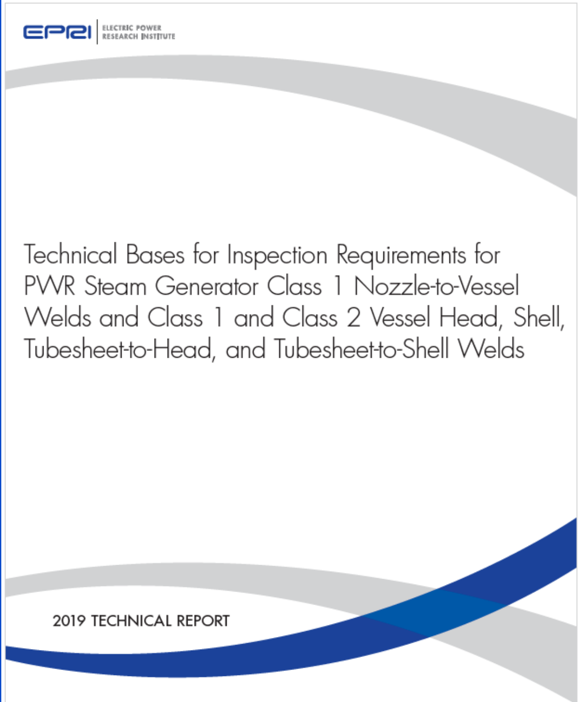
- EPRI developed a **series of technical reports** establishing the technical bases **for optimizing examination intervals** for the components listed in each report title below.
- Following publication of the EPRI technical bases for optimization of NDE examination intervals, several pilot plants submitted "Requests for Alternative" to the US NRC and were granted permission to use the new intervals via Safety Evaluation Reports (SERs)


EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Technical Bases for Inspection Requirements for PWR Steam Generator Feedwater and Main Steam Nozzle-to-Shell Welds and Nozzle Inside Radius Sections

2019 TECHNICAL REPORT

EPRI Report 3002014590


EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Technical Bases for Inspection Requirements for PWR Steam Generator Class 1 Nozzle-to-Vessel Welds and Class 1 and Class 2 Vessel Head, Shell, Tubesheet-to-Head, and Tubesheet-to-Shell Welds

2019 TECHNICAL REPORT

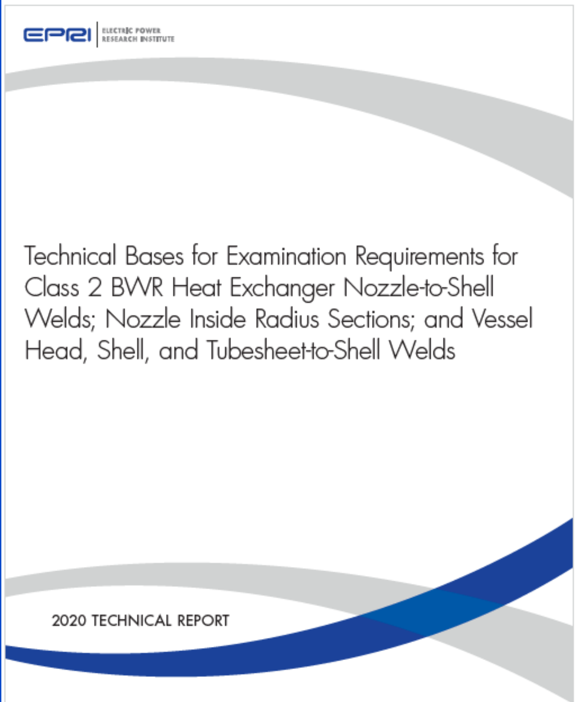
EPRI Report 3002015906


EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Technical Bases for Inspection Requirements for PWR Pressurizer Head, Shell-to-Head, and Nozzle-to-Vessel Welds

2019 TECHNICAL REPORT

EPRI Report 3002015905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Technical Bases for Examination Requirements for Class 2 BWR Heat Exchanger Nozzle-to-Shell Welds; Nozzle Inside Radius Sections; and Vessel Head, Shell, and Tubesheet-to-Shell Welds

2020 TECHNICAL REPORT

EPRI Report 3002018473

Results (2/2)

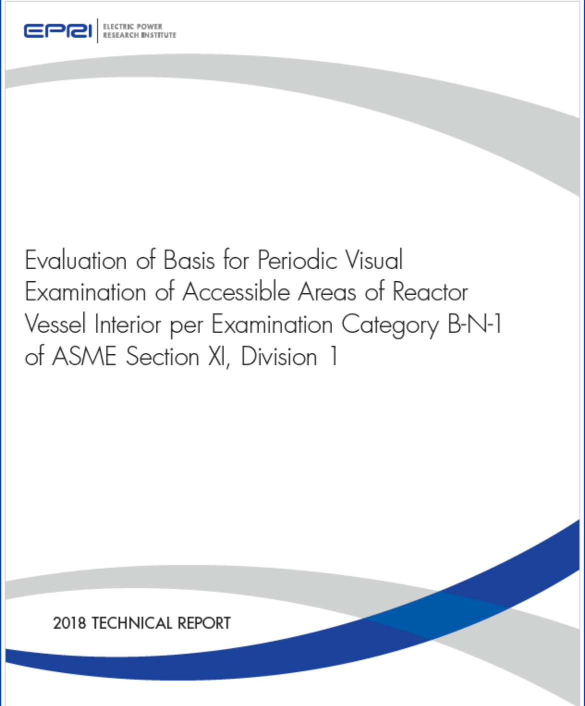
- EPRI developed a **series of technical reports** establishing the technical bases **for optimizing examination intervals** for the components listed in each report title below.
- Following publication of the EPRI technical bases for optimization of NDE examination intervals, several pilot plants submitted “Requests for Alternative” to the US NRC and were granted permission to use the new intervals via Safety Evaluation Reports (SERs)


EPRI

Technical Bases for Inspection Requirements for PWR Steam Generator Auxiliary Feedwater Nozzle-to-Shell Welds

2022 TECHNICAL REPORT

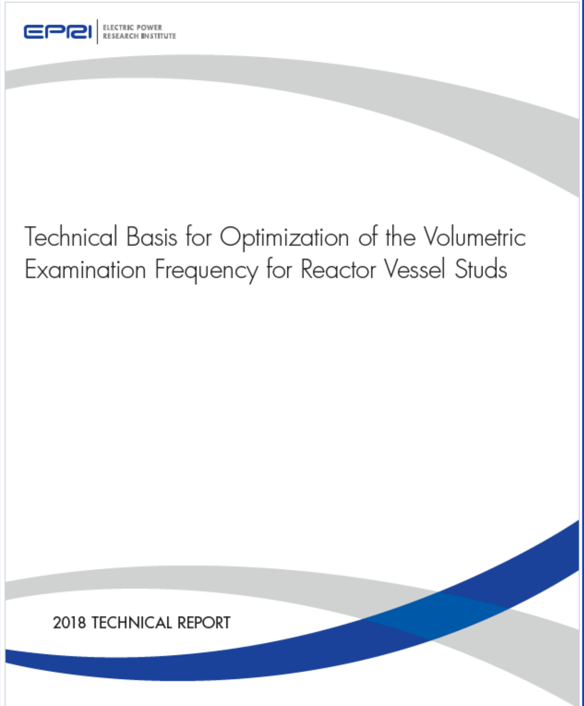
EPRI Report 3002023713


EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Evaluation of Basis for Periodic Visual Examination of Accessible Areas of Reactor Vessel Interior per Examination Category B-N-1 of ASME Section XI, Division 1

2018 TECHNICAL REPORT

EPRI Report 3002012966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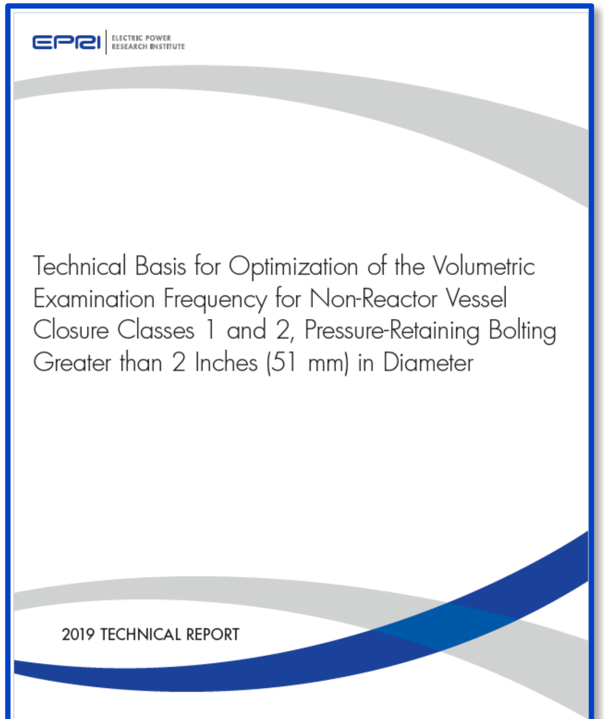
Technical Basis for Optimization of the Volumetric Examination Frequency for Reactor Vessel Studs

2018 TECHNICAL REPORT

EPRI Report 3002014589

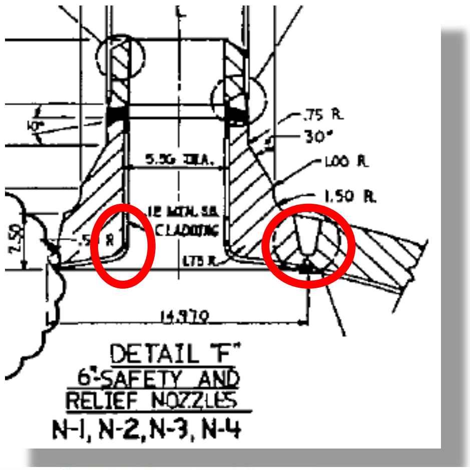

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Technical Basis for Optimization of the Volumetric Examination Frequency for Non-Reactor Vessel Closure Classes 1 and 2, Pressure-Retaining Bolting Greater than 2 Inches (51 mm) in Diameter

2019 TECHNICAL REPORT

EPRI Report 3002015907

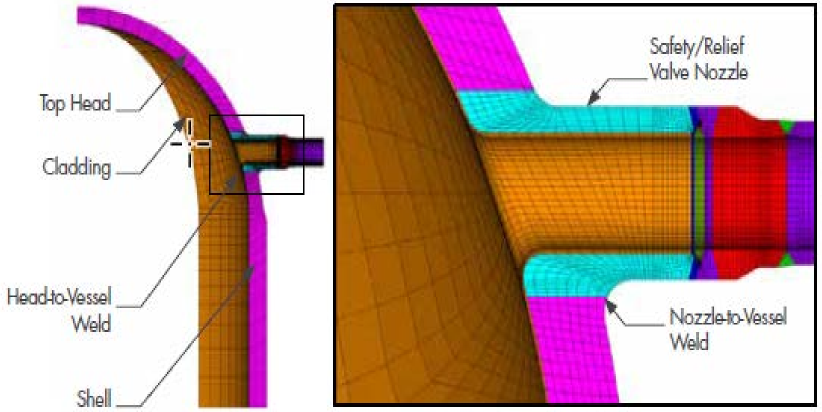
Initial US Implementation Strategy & Benefits



Industry leading utilities piloted the implementation of a series of EPRI NDE technical reports establishing the technical bases for optimizing inspection intervals of mandatory ASME component examination requirements, paving the way for other industry members to follow.

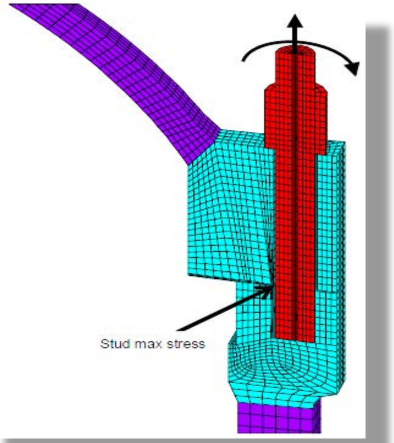
Highlights of Implementation

1. Used the NRC Request for Alternative process
2. First-of-a-Kind applications utilizing PFM as a cornerstone of the analysis
3. SERs received for all pilots allowing for optimized examination intervals up to 30 years
4. Current ASME Code actions leverage Technical Bases and SERs
5. EPRI has compiled a Lessons Learned document and relief request templates to support future submittals



Benefits

1. Maximize overall plant safety by focusing resources where they are needed (higher valued examinations)
2. Minimize health & safety risk profile of plant personnel by reducing low-value work activities
3. Potential dose savings (per unit) is on the order of multiple man-rem years
4. Potential cost savings (per unit) is on the order of millions of dollars



Industry’s Strategic Shift to
Fleet-wide Performance Monitoring Approach

Focus on Select Technical Bases

- Focus is on Steam Generator (SG) and Pressurizer (PZR) component examinations:
  - **EPRI 3002014590** - *Technical Bases for Inspection Requirements for PWR Steam Generator Feedwater and Main Steam Nozzle-to-Shell Welds and Nozzle Inside Radius Sections*
  - **EPRI 3002015906** - *Technical Bases for Inspection Requirements for PWR Steam Generator Class 1 Nozzle-to-Vessel Welds and Class 1 and Class 2 Vessel Head, Shell, Tubesheet-to-Head and Tubesheet-to-Shell Welds*
  - **EPRI 3002023713** - *Technical Bases for Inspection Requirements for PWR Steam Generator Auxiliary Feedwater Nozzle-to-Shell Welds*
  - **EPRI 3002015905** - *Technical Bases for Inspection Requirements for PWR Pressurizer Vessel Head, Shell –to-Head and Nozzle-to-Vessel Welds*
- The probabilistic and deterministic analyses for 80-years of operating life produced results that show safety margins meet or exceed the benchmark threshold of **$1X10^{-06}$**.

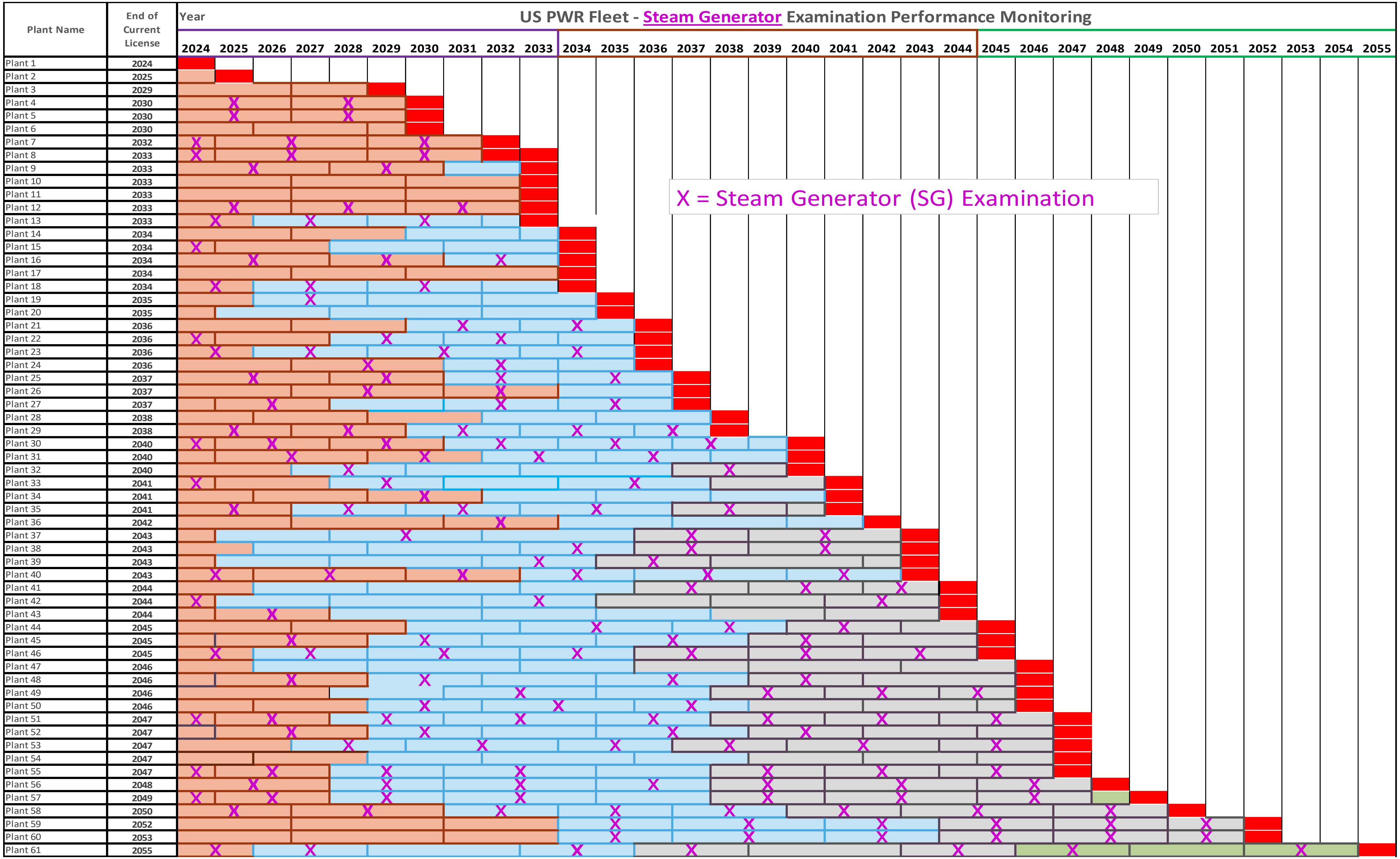
Shift in Implementation Strategy

- The US started with pilot plant applications to assess feasibility of the technical bases and process
- Relative to steam generators (SG) and pressurizers (PZR);
  - 23 (out of 61) plant sites, so far, have followed the pilot plants lead and submitted for relief through the US regulatory process
- Collectively, the US utilities have decided to shift to a fleet-wide approach; facilitating a broader, streamlined implementation strategy.
- This fleet-wide approach carries with it some additional considerations for overall performance monitoring of the SG and PZR components across the US fleet.
- There are ongoing discussions with the US NRC to determine the best approach.

The US Industry's Understanding of NRC Concerns

- How does the fleet-wide performance monitoring plan conform to:
  1. The NRC's binomial distribution model defining a minimum number of inspections that need to occur across the fleet during the current operating licenses for all plants.
  2. Sufficient, continuous collection of inspection data points, over the range of time aligned with current operating licenses for all plants, to identify known and unknown degradation mechanisms in a timely manner.
- The US utilities and EPRI are currently working to address these two concerns.
- Surveys of the US fleet were conducted to collect ISI program information for when and how many of these examinations are planned, collectively, for the entire fleet of US operating plants, through the remainder of their current operating licenses

EPRI


US PWR Fleet - Steam Generator Examination Performance Monitoring
Plant Name
End of Current License
Year
2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055
X = Steam Generator (SG) Examination
Plant 1 2024
Plant 2 2025
Plant 3 2029
Plant 4 2030
Plant 5 2030
Plant 6 2030
Plant 7 2032
Plant 8 2033
Plant 9 2033
Plant 10 2033
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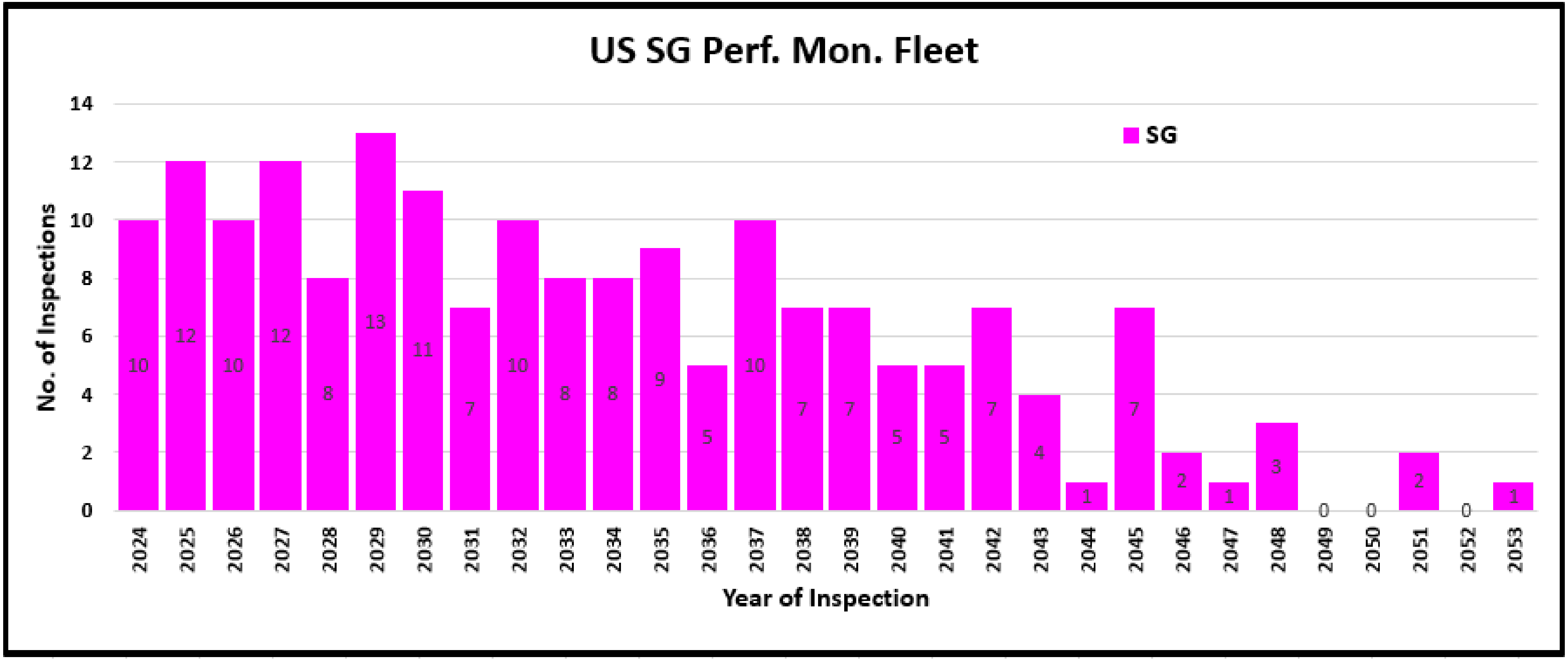
Plant 54 2047
Plant 55 2047
Plant 56 2048
Plant 57 2049
Plant 58 2050
Plant 59 2052
Plant 60 2053
Plant 61 2055

US PWR Fleet-wide Inspection Data Points Over Range of Current Operating Licenses



Fleet-wide Performance Monitoring
How Many? Which Ones? & When?

How Many? - Fleet-wide Performance Monitoring

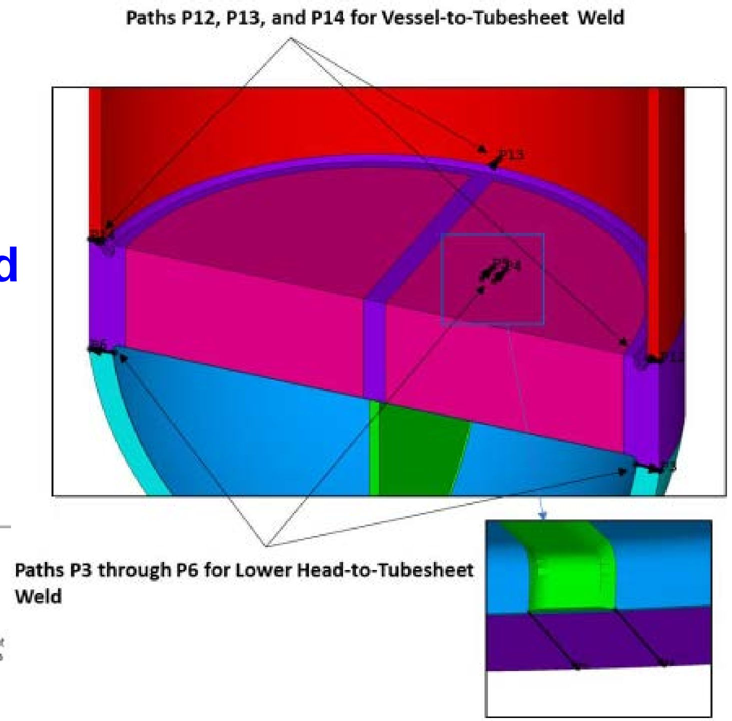
Applying the NRC Binomial Distribution Model Criterion

Parameter	SG Exams
Total # of Inspection Opportunities	930
Number of Fleet-wide Performance Monitoring (PM) Inspections to Meet 25% Criterion	232
Total number of Fleet-wide PM Inspections to be Proposed	308
Percentage of Total Opportunities for Inspection	33%

Which Items Should be Examined? – Applied Logic

- When applying the binomial distribution model, the number of examinations can range from 2 – 17 but average ~5, per unit.
- Items to be examined were determined by choosing the most critical concentrated stress paths from the FEM, per the EPRI Technical Basis

Tubesheet to Head Weld (Class 1)



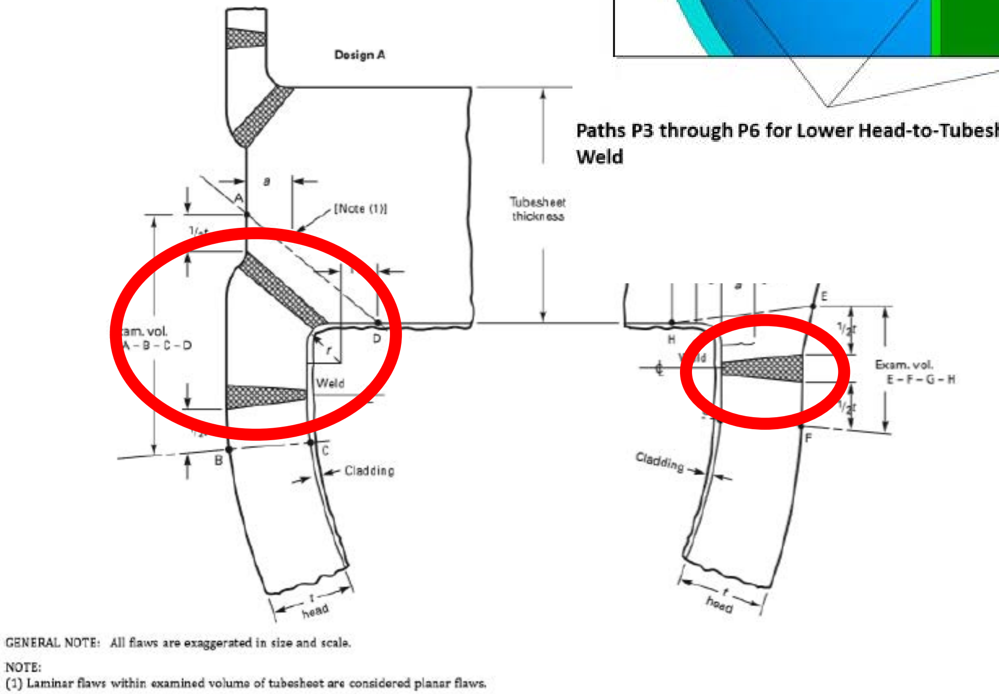


Figure 1-2
ASME Code, Section XI, Figure IWB-2500-6, Typical Tubesheet-to-Head Weld Joints (Item No. B2.40)

When Should Examinations Happen? – Distribution

- Example - Comparison of applied reduction in examination data points and distribution (Figures 1 & 2)

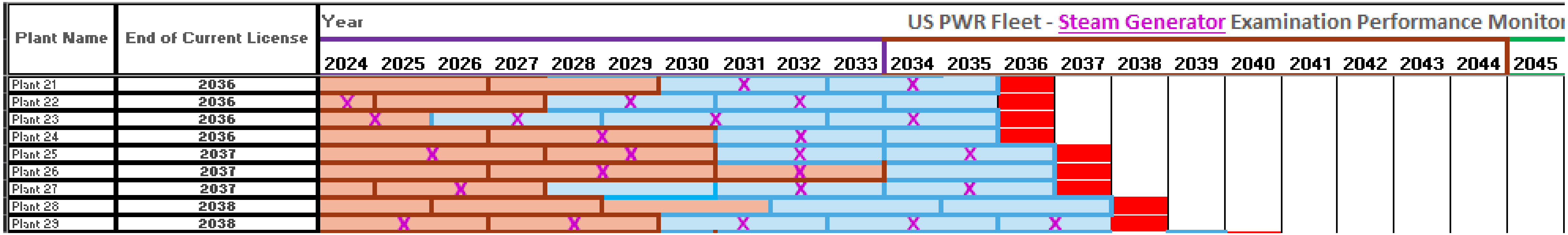


Figure 1 = 25 Examinations on original ASME 10-year interval

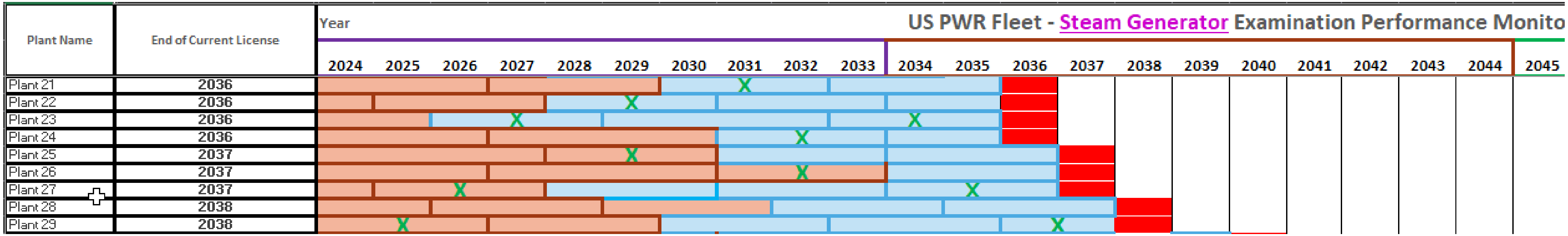


Figure 2 = 11 (Proposed) examinations based on a reduction of data points

Next Steps for the US Industry

- Finalize draft of Topical Report on performance monitoring approach
- Schedule a pre-submittal meeting with the NRC
- NEI to assist with communicating and gaining acceptance at the utility CNO level
  - Utilities will be obligated to perform the examinations as prescribed in the EPRI Topical Report
  - Utilities, through EPRI, will monitor and update the Letter Addendum
    - Periodic review
    - Reviews based on plant licensing changes
- Letter Addendum reviews and assessment will ensure regulatory concerns are still being addressed (i.e., the checks & balance on statistical relevance of data points and their distribution)

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Materials Risk Guidance Development Efforts
Risk-Informed Materials Assessment

Stephen Cumblidge, Dan Widrevitz

ACRS Meeting

November 21, 2024

Topics

- Purpose and Applicability of RIMA Project
- Defense-in-Depth
- Safety Margin
- Risk Impacts (use of risk insights)
- Performance Monitoring
- Tier List
- Sampling Considerations
- Sampling Analysis

RIMA - Purpose

Risk-Informed Materials Assessment Project

A risk-informed materials engineering forward guidance development project

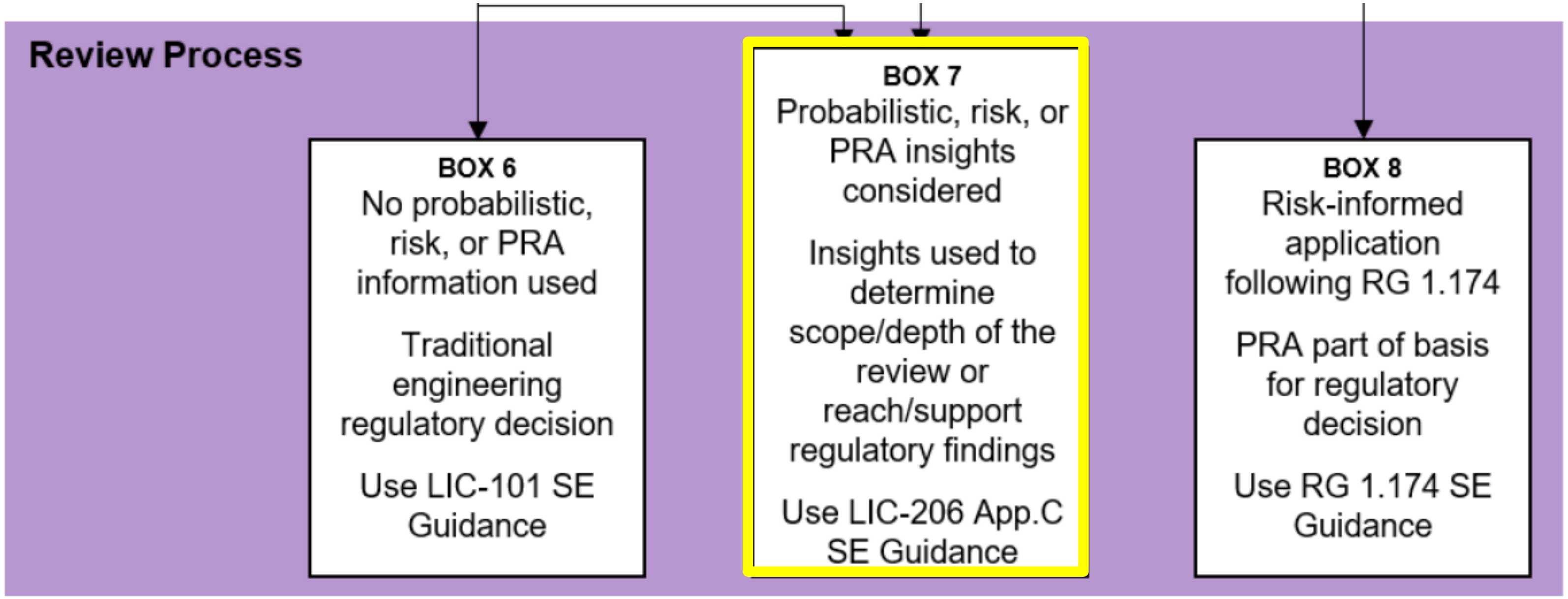
Leveraging the processes and guidance of RG 1.174, RG 1.200, LIC-206, RG 1.245, etc. to enable more efficient and effective reviews

Providing applicants and reviewers guidance in utilizing risk-informed decision making for non-integrated reviews

RIMA - Applicability

Target submittals:

LIC-206 Box 7 Type applications and reviews with non-integrated teams (e.g., materials engineers and counterparts only)



RIMA – Preliminary Concepts

Staff has been generating a preliminary set of RIMA concepts to support potential guidance document development

What it is (will be):

- Clearer/broader guidance in the language of materials engineers
- Applicant guidance to enable high quality submittals and efficient staff review

What it is not (will not be):

- New policy
- Deviation from RG 1.174

The following slides detail current preliminary concepts

RIMA – Defense in Depth

Further clarify the relationship between materials engineering topics and defense-in-depth considerations.

Typically, materials engineering reviews do not establish defense-in-depth characterizations, rather materials engineering supports commensurate level of assurance based on characterization.

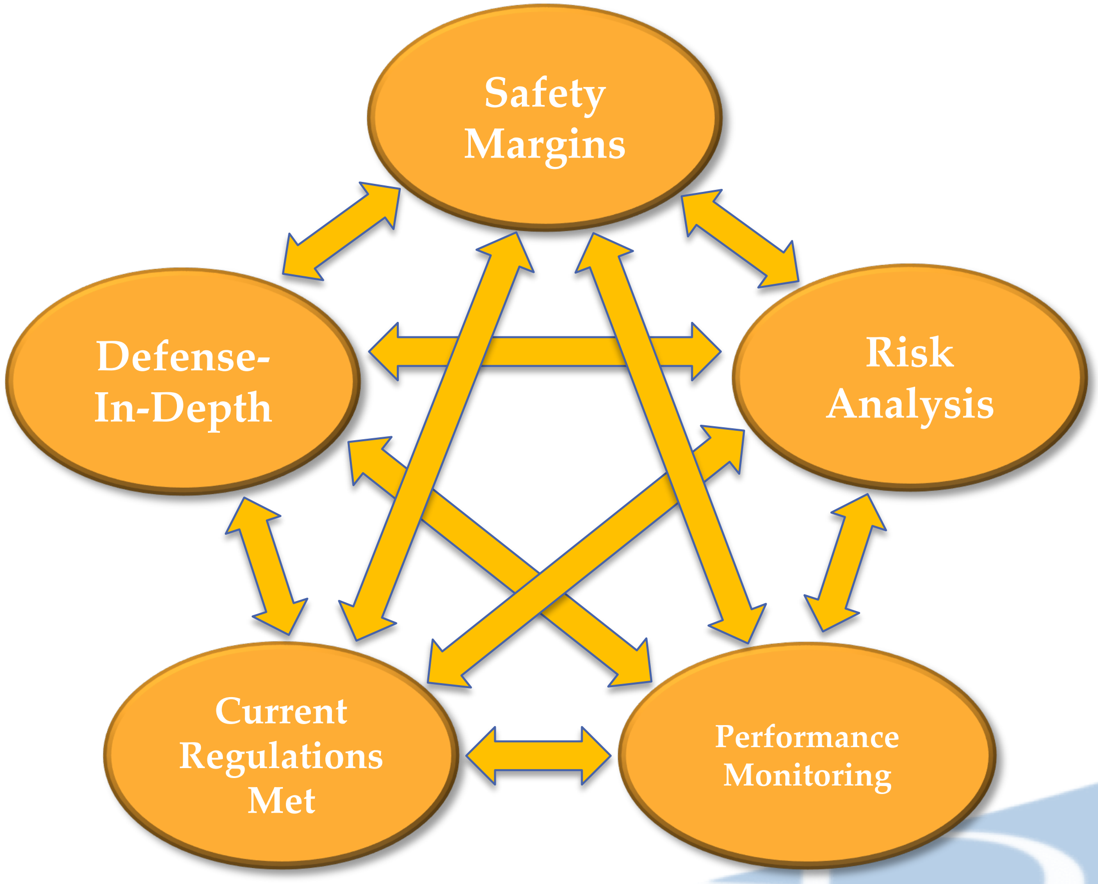
Is treatment of subject systems commensurate with defense-in-depth functions of subject systems.

RIMA

RIMA – Defense in Depth

Key consideration:

Is there enough "assurance" from other four Principles of RIDM to credit subject system for defense in depth?

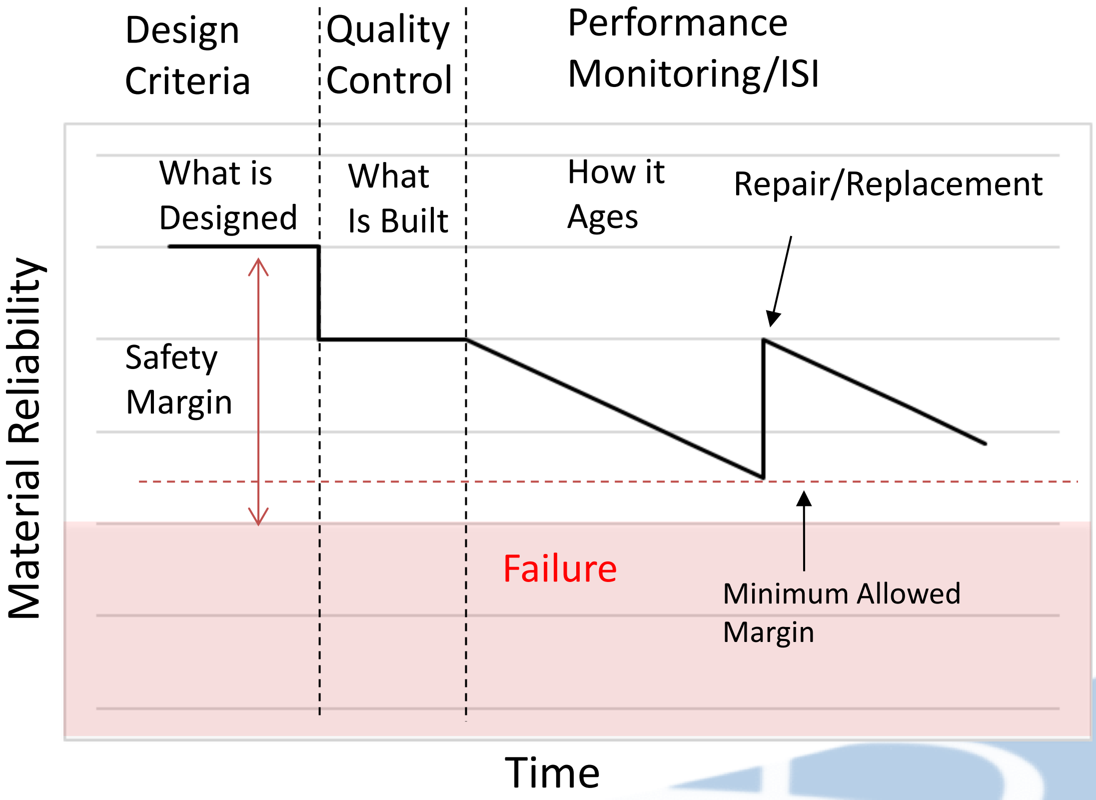


RIMA – Safety Margins

Further clarify the relationship between materials engineering topics and safety margin considerations.

Key consideration:

Are safety margins large enough, in concert with other Principles of RIDM, to manage uncertainties?



RIMA – Risk Impacts

Clarification and discussion of risk insights derived from qualitative or non-PRA modeling (e.g., PFM).

How insights related to one or more elements of the Risk Triplet (i.e., what can go wrong, how often, and what are the consequences?) can be leveraged.

(More in a few slides.)

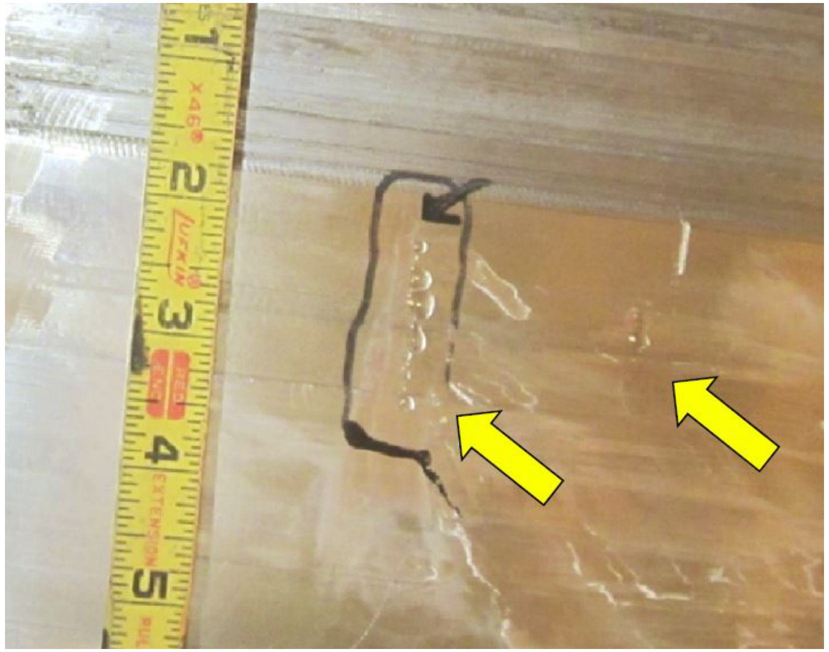
RIMA – Risk Impacts

PFM is often a Risk Impact insight:

Risk Triplet

- What can go wrong?
- ***<u>How often?</u>***
- What are the consequences?

Frequency of potential initiating event such as LOCA



RIMA – Performance Monitoring

Further clarify the relationship between materials engineering performance monitoring and the other Principles of RIDM.

Expanded discussion of performance monitoring and bathtub curve relationship.

Discussion of management of novel performance monitoring results.

RIMA – Performance Monitoring

Performance monitoring adequacy rests on several pillars.

- How much monitoring?
- What kind of monitoring?
- How often?
- Are there triggers for more or less monitoring within program?

Answers to these questions must be judged in context of other Principles of RIDM (e.g., how does subject system support defense-in-depth?)

RIMA – Tier List

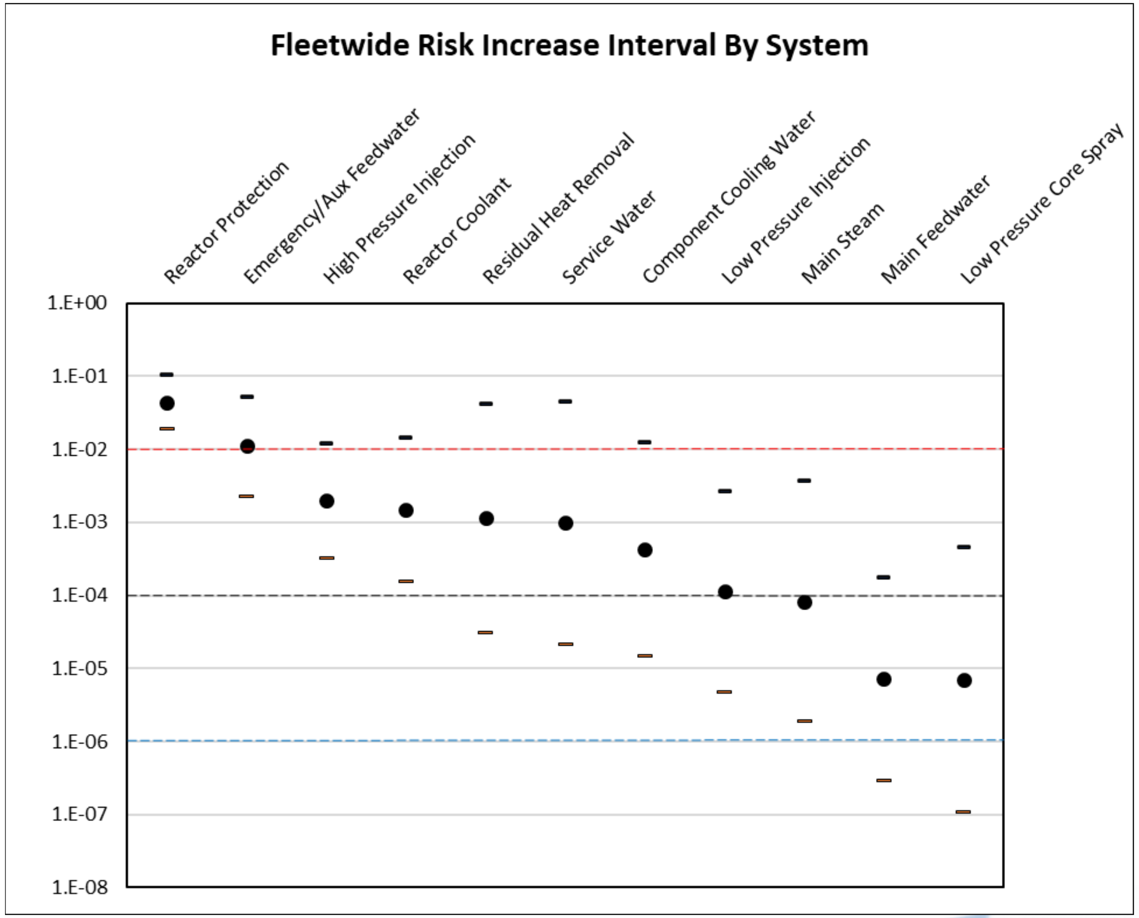
The materials staff wanted a risk ranking of important systems to help risk-inform materials reviews.

The NRC Staff used the SPAR-Dash tool to rank important systems.

For this work we have decided to focus on broad systems rather than components.

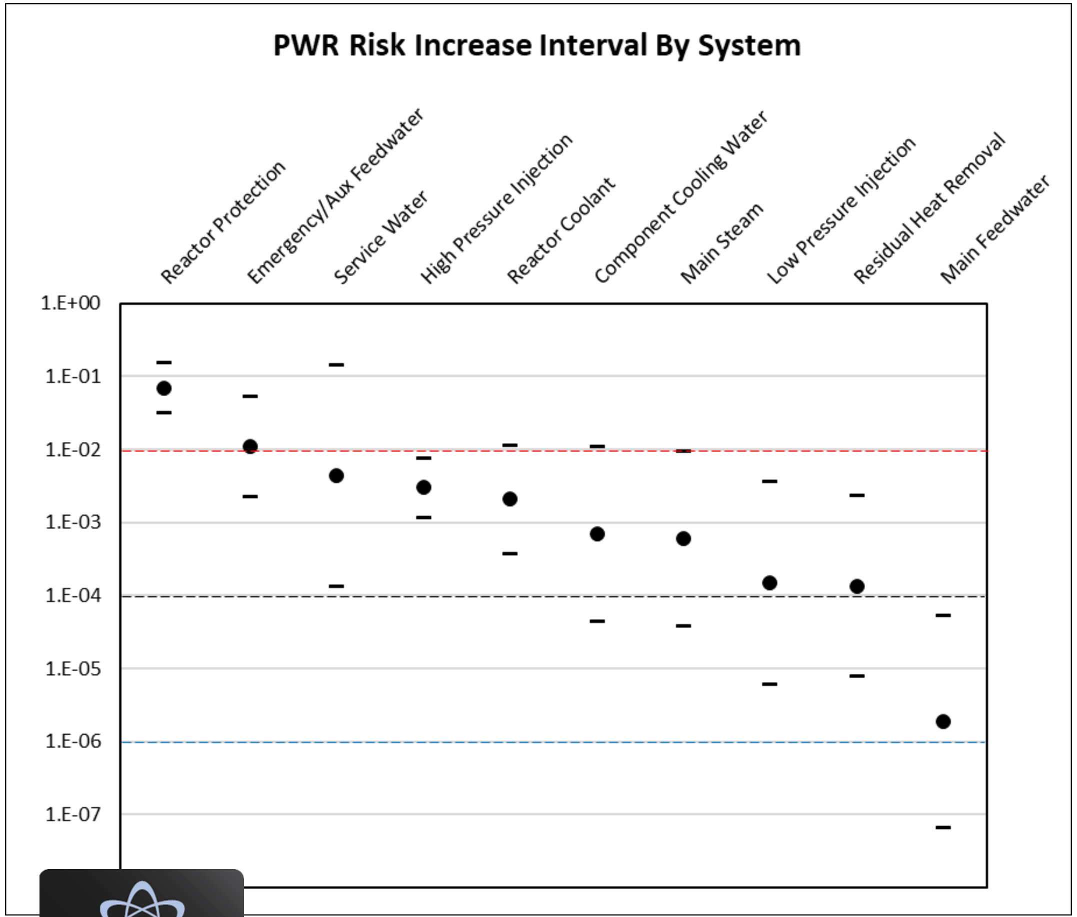
Tier List – Fleetwide System Importance

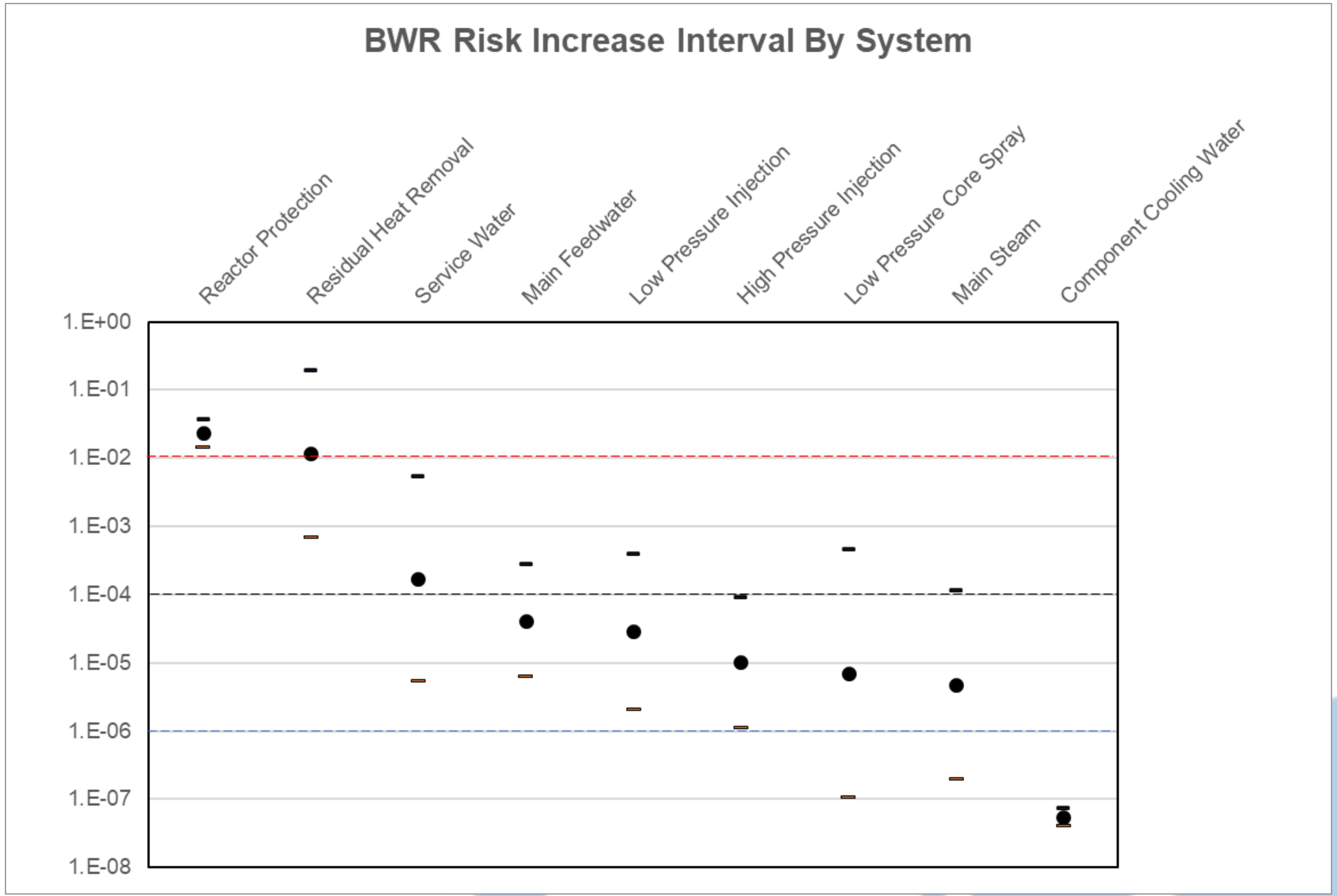
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment



RIMA

Tier List – PWR and BWR System Importance





RIMA

Tier List – Final Tier List

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

Fleetwide

Tier X	Reactor Protection Emergency/Aux Feedwater
Tier 1	High Pressure Injection Reactor Coolant Residual Heat Removal Service Water Component Cooling Water
Tier 2	Low Pressure Injection Main Steam
Tier 3	Main Feedwater Low Pressure Core Spray

PWR

Tier X	Reactor Protection Emergency/Aux Feedwater
Tier 1	Service Water High Pressure Injection Reactor Coolant Component Cooling Water Main Steam
Tier 2	Low Pressure Injection Residual Heat Removal
Tier 3	Main Feedwater

BWR

Tier X	Reactor Protection Residual Heat Removal
Tier 1	Service Water
Tier 2	Main Feedwater Low Pressure Injection
Tier 3	High Pressure Injection Low Pressure Core Spray Main Steam Component Cooling Water

* Reactor protection is not a focus for materials assessment

RIMA

Tier List – Takeaways

The Tier List is not directly applicable to individual plant reviews as there is large variability in risk significance from plant to plant for the same systems.

The risk rankings are helpful to focus attention when looking at fleet-wide issues.

The list is a tool to teach new staff about the importance of different systems.

The list does not consider internal flooding.

RIMA – Sampling Considerations

Expanded discussion of performance monitoring including framework to help identify target concepts supporting optimization of performance monitoring

Includes discussion of qualitative factors as well as an example statistically driven sampling calculation

Leverage bathtub curve terminology to create common language for discussion

RIMA – Sampling Considerations

The following tables are initial thoughts regarding the impact of various considerations on necessary sampling.

✓ - Means a consideration likely indicates a particular column applies

↑ - Means a consideration increases emphasis

↓ - Means a consideration decreases emphasis

Color ↓ vs. ↓ implies a stronger or weaker association between a consideration and a particular column.

RIMA

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Generic life-stage determination table

	Burn-in	Maturity	Wear-out
Novel material, process, or design	✓		
Novel repair	✓		
Repair	✓	✓	
Novel degradation mechanism identified	✓		✓
Novel degradation parameters (CGR, etc.)	✓		✓
Degradation threatening function			✓
PSI only	✓		
PSI + 1 interval of ISI	✓		
PSI + more than 1 intervals of ISI	✓	✓	

* Checks in multiple columns are "ors"

RIMA

Sampling Considerations – Qualitative Factors

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Qualitative factors affecting sampling intensity table

	Component level sampling	Population Level sampling
Burn-in	✓	✓
Maturity period	✓	✓
Wear-out	✓	✓
Safety related	↑	↑
RISC-2 (50.69 approved designation, system designation)	↑	↑
Consequence significant	↑	↑
Aging management program	↑	↑
Failure tolerant (LBB, etc.)	↓	
Low impact on other safety significant systems	↓	
Redundant	↓	
Isolable	↓	

* Gray marks indicate that column should be considered but is not a priori necessary

RIMA

Sampling Considerations – Emergent Events

Qualitative factors affecting sampling due to emerging events table

	Component level sampling	Population level sampling	Site sampling expansion	Population sampling expansion
Site-specific event or chemistry issue		↑	↑	
Novel indications identified at a single site			↑	↑
Novel indications identified at multiple sites			↑	↑
OE limitations (e.g. low coverages or other issues)	↑	↑		
Extensive OE demonstrating no degradation	↓	✓		
Extensive OE demonstrating limited degradation	↓	✓		
Extensive OE demonstrating unmodeled degradation	✓	✓	↑	↑
Extensive OE demonstrating modeled degradation	✓	✓		

* Marks in multiple columns are all applicable or should be considered (if gray)

RIMA

RIMA – Sampling Analysis

Quantitative sampling calculation can be derived from statistical calculations

For example, NRC staff leveraged this in support of review of PROMISE Code submittals

Detailed discussion of approach in PVP2023-105203, *Statistical Approach to Developing a Performance Monitoring Program*

Binomial Distribution

- The binomial distribution is frequently used to model the number of successes in a sample of size n drawn with replacement from a population of size N
- Can be used to find number of inspections needed to find a crack
- Only a function of the number of inspections and the percentage cracked
- Very easy to use (beware of limitations)

$$f(k,n,p) = \binom{n}{k} p^k (1-p)^{n-k}$$

$$\binom{n}{k} = \frac{n!}{k!\,(n-k)!}$$

k= number of successes (cracks found)
n=number of trials (inspections)
p= probability of success on an individual trial (percentage of population cracked)
If k=0 then this is the probability of no successes is:

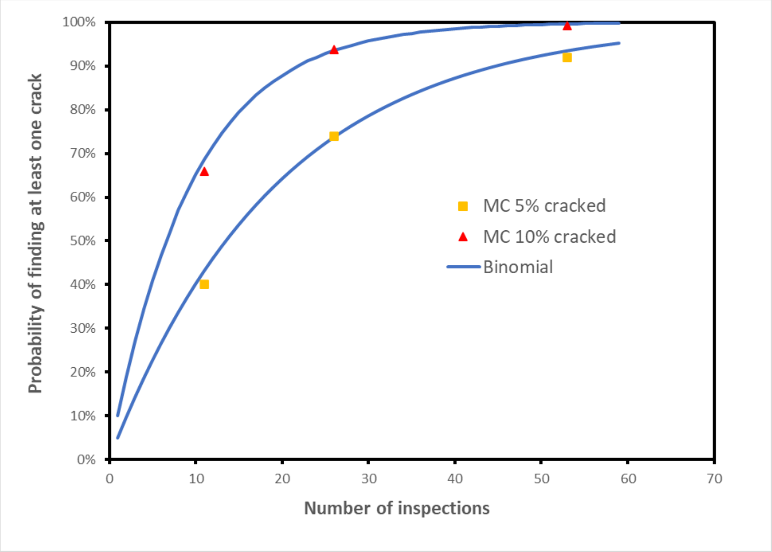
$$f(n,p) = (1-p)^n$$

and therefore, the probability of at least one success is:

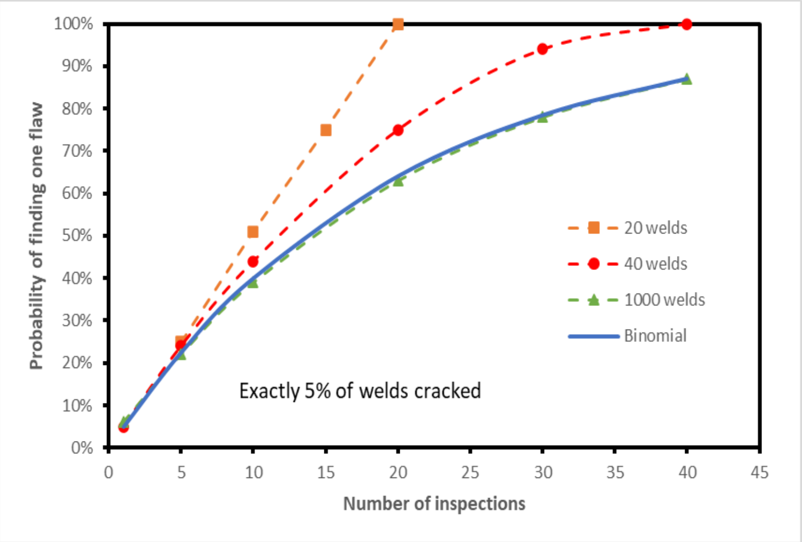
$$1 - f(n,p)$$

Monte Carlo Analysis

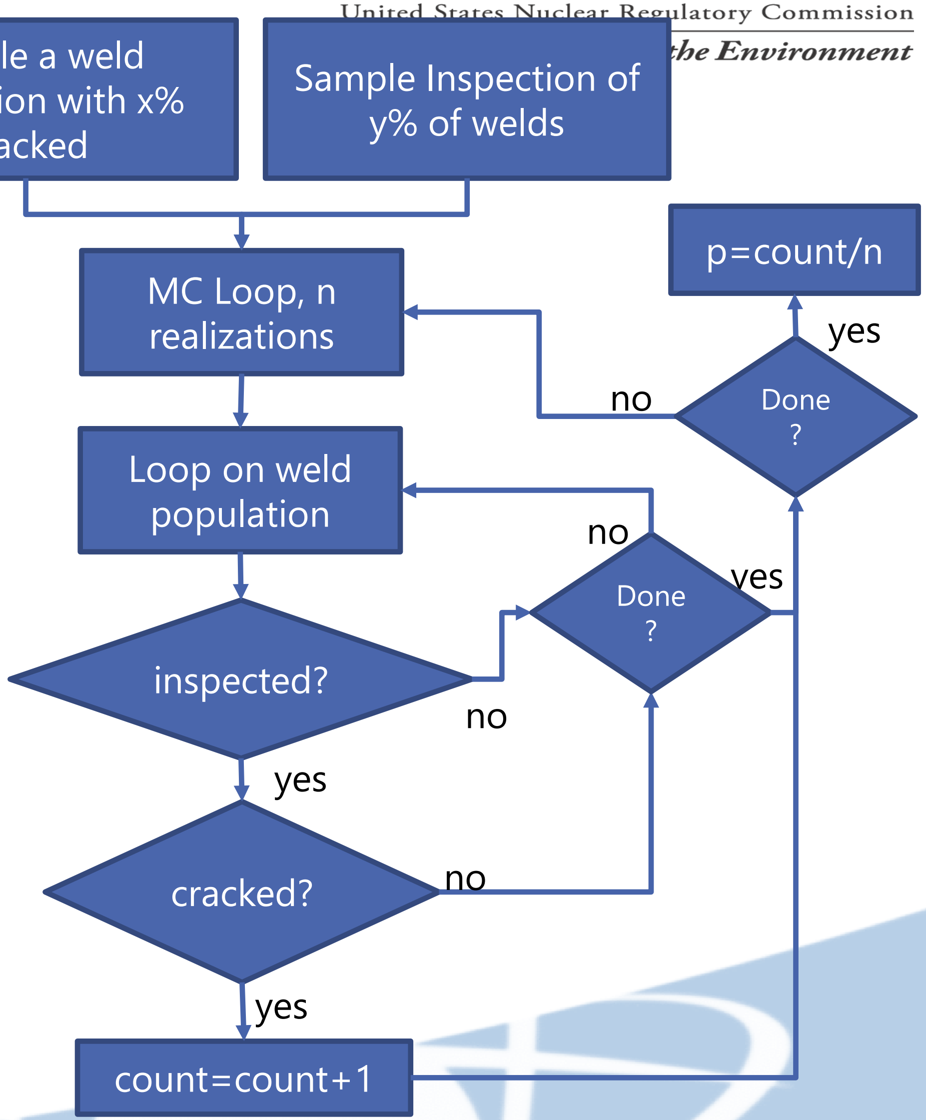
- Same idea can be developed through a MC analysis
- Allows maximum flexibility in analysis
- Binomial response can be recreated



For large populations



For small populations



Combining insights from Sampling Consideration slides with Sampling Analysis approaches allows for high quality proposals in performance monitoring space

Take Aways

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- RIMA Project aims to build forward from RG 1.174 and similar guidance in materials engineering specific language
- Focus is on non-integrated (e.g., NRC materials engineer reviewer only) submittals
- Guidance on all five Principles of RIDM to be translated and extended
- Tier List and Sampling Considerations provide increased domain specific granularity of guidance

RIMA