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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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THERMAL-HYDRAULIC ACCIDENT ANALYSIS SUBCOMMITTEE

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TUESDAY

OCTOBER 1, 2024

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The Subcommittee met via Teleconference, at 8:30 a.m. EDT, Robert P. Martin, Chair, presiding.

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DENNIS BLEY

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

MICHAEL SNODDERLY

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

8:30 a.m.

CHAIR MARTIN: This meeting will now come to order. This is a meeting of the Accident Analysis Subcommittee of the Advisory Committee on Reactor Safeguards. I am Robert Martin, chair of today's subcommittee meeting.

ACRS members in attendance in person, Ron Ballinger, Craig Harrington, Roberts, Petti, Halnon, Kirchner, Vicki Bier, Scott Palmtag. Anybody else? And then online, we should have Matt Sunseri and Vesna Dimitrijevic. Do we have anybody else? I guess our consultants, we have Dennis. Yeah, there's Dennis on there and Steve Schultz, correct? Is Charlie on? Did Charlie join us?

Okay, all right, Mike Snodderly of the ACRS staff is the designated federal officer for this meeting. No member conflicts of interest were identified for today's meeting and we have a quorum for today's meeting.

The subject of today's meeting is Accident Selection in Support of Emergency Planning and Siting Analysis. Accident selection is determined by considering design features that influence event progression and their ability to prevent or mitigate hazards impacting facility safety and the public.

Safety-in-design through defense-in-depth has been a hallmark of the NRC's reactor safety framework, integrating both accident prevention and mitigation. Assessment of accident mitigation assumes prevention has failed, leaving the remaining layers of defense to minimize harm to the public.

The methodology for the selection of accident scenarios for these assessments has evolved over time, influenced by regulatory updates such as 10 CFR 50.160, most recently, which specifically addresses emergency preparedness for small modular reactors and non-light-water reactors.

Balancing its safety mission with the demand for the efficient reviews of advanced reactor designs, the NRC has shifted toward a technology-inclusive regulatory framework. This framework emphasizes risk insights, revealing safety margins across the domain of anticipated, design-basis, and beyond-design-basis events. This change provides flexibility in evaluating containment design, siting, and emergency planning criteria.

The ACRS has been very much involved with this evolving regulatory framework as it applies to these topics. A few specific examples of such engagements include our review of Reg Guide 1.233, Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors, and that was in 2020, then the NuScale SMR's EPZ in 2022, and Rev. 1, most recently, Rev. 1 of Reg Guide 1.183, Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Plants.

We have acknowledged the benefits of the regulatory shift, but we have also noted the need for clearer guidance on accident selection, or accident scenario selection, defense-in-depth, and cliff-edge effects. Today, we will hear from the staff on these topics and their expectations for advanced reactor designs.

The ACRS was established by statute. It is governed by the Federal Advisory Committee Act, or FACA. The NRC implements FACA in accordance with its regulations. Per these regulations and the committee's bylaws, the ACRS speaks only through its published letter reports.

All member comments should be regarded as only the individual opinion of that member and not a committee position. All relevant information related to ACRS activities, such as letters, rules for meeting participation, and transcripts are located on the NRC public website and can be easily found by typing About Us ACRS in the search field on the NRC home page.

The ACRS, consistent with the Agency's value of public transparency in regulation of nuclear facilities, provides opportunity for public input and comment during these 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 this meeting for public comments.

The ACRS will gather information, analyze relevant issues and facts, and formulate proposed conclusions and recommendations, as appropriate, for deliberation by the full committee.

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, and if you are not speaking, please mute your computer on Teams or by pressing star-6 if you're on your phone.

Please do not use the Teams chat feature to conduct sidebar discussions related to the presentations. Rather, limit use of the meeting chat function to report IT problems. For everyone in the room, please put all 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 the ceiling microphones are live.

For the presenters, your table microphones are unidirectional and you'll need to speak into the front of the microphone to be heard. Finally, if you have any feedback for the ACRS about today's meeting, we encourage you to fill out the public meeting feedback form on the NRC's website. We will now proceed with our meeting. So, we have the staff before us here. I don't know who -- who are we beginning with? Is it --

MR. RECKLEY: This is Bill Reckley. I'll start. Steve, did you want to say anything, Steve Lynch?

MR. LYNCH: Good morning, everyone. I am Steve Lynch, Chief of the Advanced Reactor Policy Branch at the NRC. I'm glad to be supporting the staff today, and all I want to do is thank the members for their time, and sharing their insights, and considering this important topic, as we continue to enhance the NRC's regulatory framework to accommodate new designs and an advanced reactor that is already in front of us, so thank you so much for your time today.

MR. RECKLEY: Others? I'm joined at the front by Todd Smith, Senior Level Advisor for Emergency Preparedness out of NSIR, Michelle Hart, Senior Reactor Engineer, who will be talking about the Reg Guide 1.183 source term calculations, offsite dose, and Anders Gilbertson with our probabilistic risk assessment.

So, at today's meeting, we're going to go over some of the evolution of accident analysis and how we've considered actual offsite consequence assessments in terms of both siting and emergency preparedness.

We'll get into, in the second segment, guidance on accident selection for demonstrating site suitability under Part 100. That will largely be a summary of our most recent revision to Reg Guide 4.7, site suitability, and then we'll end with a discussion on defense-in-depth and the related topic of how we address cliff-edge effects.

So, you know, the protection of the public from radiological hazards is our primary mission, so it's not surprising that it shows up in a variety of places, although to me, it's somewhat surprising how often or how little we actually talk about offsite consequences when we're talking about reactor safety. It's usually the discussions of barrier protection and things like that, but we do actually consider analysis of potential offsite consequences in a number of areas.

The first, although we're not going to talk about it in-depth today, is routine operations. This is normal effluents, routine operations. That's governed by Part 20 of our regulations, also regulations within Part 50, Appendix I, related to keeping doses to members of the public as low as reasonably achievable as it relates to routine effluents, and then other regulations in Parts 50 and 52.

The focus of today's discussion will be more the unplanned releases, those that are coming from transients and accidents, and the topics related to that are the traditional Chapter 15 accident analysis.

Again, most of those don't actually go as far as computing offsite consequences in the traditional light water reactor analysis. They're focused on barriers like reactor coolant pressure boundary, reactor fuel cladding, and the containment.

We do have a specific and rather central assessment that we do, and that's the design basis radiological consequence analysis. It's often referred to as the siting analysis. That used to be primarily in Part 100. It's now in both Part 100 and in Parts 50 and 52 in terms of the regulatory controls related to that particular assessment, and we'll be getting into that in more detail.

As was mentioned, you see things like revisions to Reg Guide 1.183, which is the central guidance document for that assessment for traditional light water reactors. Then we also looked at population density considerations. I'll get into that discussion. Obviously, emergency preparedness, we'll talk about that later today.

Then over time, and we'll get into the history on the next slide, but over time, we also started to look at severe accident considerations, what would be appropriate to address accidents that progressed past core melt for light water reactors, the assessment of the NRC safety bills, and we used offsite radiological consequence assessments when we do backfit analyses or cost benefit analyses.

CHAIR MARTIN: Before you leave that slide, I wanted to ask you about -- well, I tried to do a little historical context before the meeting, and so I was pulling the thread on accident selection, and really, I wanted to know where Class 9 came from.

MR. RECKLEY: All right.

CHAIR MARTIN: So, it comes from a proposed Appendix D to 10 CFR 50, which was back in 1971, which generated a lot of public comment and subsequently was withdrawn.

Now, I have some personal experience, just a little bit, with the environmental, you know, report, and SAMDA, and what have you. That's very much a technical analysis. Where does -- I think it's because it's really now implemented in 10 CFR 51, right? Where does all of that fit into this story?

MR. RECKLEY: Okay, and if you'll grant me about three slides from now --

CHAIR MARTIN: Okay.

MR. RECKLEY: -- we'll start to get into that --

CHAIR MARTIN: That's fine.

MR. RECKLEY: -- and then in the three or four slides, we'll try to show that context.

CHAIR MARTIN: Okay, perfect. Thank you.

MR. RECKLEY: Thank you. So, in this slide, I'll use -- it's not used very much within the nuclear industry, but I started to use it when we were coming actually before the ACRS to talk about Part 53 as a way to show kind of an integrated approach, and to some degree, we'll get -- for example, the environmental effects is one of the places we addressed consequences, so you'll see that in the bottom right, environmental impact.

So, but just since I'm going to use it a number of times today, the bow-tie diagram is simply a representation of you start with the threat or an event, you have certain prevention controls that is intended to stop you from reaching a top level event, and then should the top level event happen, you have certain mitigating barriers or controls that would address potential consequences.

So, a non-nuclear example, if a top level event is losing control of a car in the rain and hitting a tree, and that's the top level event, well, the rain might be the initiator. Prevention would be things like slowing down in the rain, an operator control.

It might be anti-lock brakes and those things that are built into the car to try to keep you in control, but should you lose control and hit the tree, then the mitigating measures are things like seatbelts, airbags to try to prevent the consequence of serious injury or death.

So, that's the non-nuclear example. For light water reactors, this has worked pretty well to characterize what we do, and the top level event is usually provided as core damage, and we'll get into a little bit more detail as we go forward.

CHAIR MARTIN: Let me follow up on this slide too. So, I've done this a number of times in other meetings to bring up the topic of hazards analysis, some feedback that I've provided in those previous meetings is that while hazards analysis is mentioned numerous places, there's a lack of formality in the process with one exception, and that is the integrated safety analysis that is associated with fuel cycle activities, so that's not a 10 CFR 50 activity.

But in fact, with the fuel cycle stuff, we do have the NUREG, I want to say 15, 17, or something like that. The explanation of what is required for hazard analysis is fairly well-articulated. I mean, you could always get into more detail. And as someone that has worked in that domain and has prepared hazard -- there can be a lot of ambiguity and maybe inefficiency with the exercise of doing the hazards analysis, you know, to really ferret out really what's important and what are the safety issues.

And even one of the objectives of this meeting or motivations for this meeting was to bring some clarity and motivate some more kind of coherent, transparent type presentation of the content.

I'll acknowledge when it comes to, say, beyond-design-basis accidents in particular, the explanation of what might be required by an applicant is really spread out over a lot of things, and the regulatory guide, for instance, that starts to put guardrails and encourage that efficiency is valued.

And I'm trying to, you know, bring this around to more of a question than a comment, but, I mean, what is the opportunity maybe as an action, not necessarily as an information meeting, so we also have actions at least in the formal sense, but to bring about, you know, change to improve the coherency of, you know, all of the information it is that relates to this topic?

MR. RECKLEY: So, there's a couple items. First, as we've -- the lower left here in this slide, the revised approaches that we've tried to develop because we're faced with new reactor technologies, or at least new to our regulatory exercises, or ones we haven't visited in a long time. We needed to revisit exactly the things you're talking about in terms of how to evaluate hazards, because the hazards will depend on the reactor technologies.

Whereas, the traditional approach for light water reactors has been built over many decades based on operating experience, risk assessments, and so forth to address what events to assess, and then again, add it to that. For instance, after Three Mile Island, we started to look more at severe accidents.

As we got in and started to build Part 53, for example, and one of the things, and Anders, you can help me with the number because I forget, but one of the things, and this was actually stressed by your consultant, Dennis Bley, when he was at committee, and other ACRS members, that we needed to address these things with what some call a blank sheet, a blank slate, so that we're assessing the actual hazards related to technologies.

So, for Part 53, we do have a draft guide, and it's unique among the guides we're issuing with Part 53 because it's applicable to both 50, 52, and the proposed 53, but it is our guidance on identifying and assessing hazards. So, do you recall the number?

MR. GILBERTSON: Yeah, this is Anders

Gilbertson of the staff at NRR. It's DG-1414.

CHAIR MARTIN: Yeah, I think we've had some exposure to that previously.

MR. RECKLEY: At least when it came through Part 53, the committee got an opportunity to look at it, so, and we'll revisit this as we go through the topics.

MEMBER KIRCHNER: So, Bill, since you brought that up, what is the status of that guide? Because that was one that the committee really felt would be very valuable to have out there.

MR. RECKLEY: So, that guide will go out with the proposed rulemaking for public comment, which the package, I think, as you're all aware, is with the Commission now. We expect to send it to the Federal Register next week, and that guide would be one of the things that would be open --

MEMBER KIRCHNER: It would be part of the package.

MR. RECKLEY: Part of the package open for public comment. And then from the ACRS standpoint, we'll come back as we do that final rulemaking and the final regulatory guide. That would be in 2025 and we're already starting to talk about scheduling some meetings. Anders, if we could go to the next slide?

So, this does get into how we ended up where we are, the evolution of approaches. And we remain relatively well-rooted in what the Atomic Energy Commission started in about 1960, and so that initial proposal from the Atomic Energy Commission on the licensing of commercial nuclear plants really focused on what was different terminology, sometimes maximum credible accident is one that's often used, and for light water reactors, that was a large break loss of coolant accident.

Chairman Martin, you mentioned Class 9. In the assessment of events or accidents, there was a categorization system that went from Class 1 and went up through Class 9, with Class 8 being basically the loss of coolant accident and Class 9 being core melt and what we would in today's terms call severe accidents.

Now, the initial proposals, and this went all the way through the draft, the publication of draft Appendix D and so forth that you were mentioning, Class 9 accidents were excluded from licensing based on low frequency, low anticipated frequencies. So, the licensing and the environmental reviews were Class 1 through 8 and Class 9 excluded.

Around late '70s, 1980, you had the

reactor safety study published, and in 1979, as we all know, we had the accident at Three Mile Island, and that changed the thinking and the rationale for excluding Class 9 accidents, and that led then to a flurry of activity in the 1980s.

Jumping down one, there was a whole series of Commission policy statements, like the severe accident policy statement for example. It also led to a series of studies like NUREG-0625, which was a siting policy taskforce, NUREG-0396, which Todd will probably mention, and it was an NRC EPA taskforce on emergency planning, and environmental reviews we took back after that that, hey, you don't need to consider Class 9 accidents in environmental reviews.

That was ultimately, a few years after that, challenged in a court case that brought about our actual calculations of severe accident management alternatives, SAMAs or SAMDAs at the design stage, as a result of the court case, but there was already talk in that direction after Three Mile Island that maybe it was prudent to look at severe accidents as a licensing matter, as an environmental matter.

MEMBER ROBERTS: Hey, Bill, this is Tom Roberts. Could I ask you about some parts of history that are missing and get your perspective on that?

I'll start with the 1960, '62 time frame. The AEC did consider severe accidents in their accompanying dialogue with the 10 CFR 100 rulemaking. They said that the population center distance was the surrogate for severe accidents for the scenarios studied up to date, and then there was need for more study to see if that remained the case.

And then several years later, there was the 1968 report on emergency core cooling where the Commission was concerned that there was a potential common cause between the loss of coolant accident and containment failure, and so there wasn't a diversity of barriers that was previously thought.

There was a whole flurry of rules that came out of that, including Appendix K and a focus on emergency core cooling systems, as well as the general design criteria tying containment function to emergency core cooling, so it was clearly acknowledged that they were not independent barriers.

And then going forward, some of the studies you listed were, of course, written on, as a matter of fact, most of them, because throughout the '60s and '70s, the AEC and the NRC were uncomfortable with the 10 CFR 100 criteria being sufficient, and they found ways to reject various sites based on population density considerations, regardless of what 10 CFR 100 said.

So, it seems like there was kind of a discomfort with the design basis manual maximum credible accident approach dating back to almost the onset of 10 CFR 100, and the concern about severe accidents obviously became more, you know, more clear after Three Mile Island.

I think that was part of the thought process all along. Like Bob said, 1971 is when this term first came out as a Class 9. So, anyway, I just wanted to get your perspective on that. It seems like there's a lot that --

MR. RECKLEY: There is definitely a lot of history missing from this slide, so you're exactly right. I mean, if you go back, and this is my own personal view, and you could get the historian to come if you wanted to and speak for days, but, you know, the development of nuclear power, one of the first things was to site them out, you know, the National Labs in Idaho or various places, and isolation was a key factor.

Then that can't hold, right? You can't have all of your commercial nuclear plants located in isolated areas, so containment was the next thing, and that really led to what we'll talk about, the TID, and the siting study of what would be needed to get them a little closer, but you're exactly right, then how far do you take that?

With the containment, the proposal to put a power plant in close proximity to Manhattan in Ravenswood, it was like well, maybe two containments will work, or maybe it's better not to put it in New York City, so that was, you know, that was the discussion that -- and you're right. This was being done and evolving all the way from the beginning. Then, yeah, as we learned more, we did experiments, and Dave can lay in.

We did, you know, the experiments at LOFT and other things that said hey, ECCS may not work as well as we thought, so then we did the ECCS rulemaking in the mid-1970s, but, you know, that was really kind of well into, if you want to look at it, well into the path of commercializing nuclear power to realize hey, we need to do something like have an emergency core cooling rule.

So, yes, there's a lot of history that's not on this slide, and it's all interwoven because the subjects that we're going to talk about, reactor design, siting, the need for emergency planning, emergency preparedness, all of that is kind of interrelated and it's evolved.

I just, I was trying to use here that the accident at TMI was kind of a change in the regulatory mindset, because up to that point, we found a reason to exclude severe accidents, and after that, we started to build it into processes and decision-making. So, to me, that was a break point, but there's plenty of other examples, plenty of other lessons learned.

Then in the 1980s, again, the Commission policy statements on severe accidents, the whole containment program that was undertaken after Three Mile Island, but then it also started to look at how do we move past Three Mile Island? And you had advanced reactor policy statements, PRA policy statements, the NRC safety goals to try to say, you know, we're not finished. What do we need to do to make adjustments going forward?

With the reactor safety study, it initiated a whole series of risk-informed performance-based initiatives that have been ongoing really since that time, and then more recently, the advanced reactors and our move to try to find more technology-inclusive ways of going forward, and we'll talk about that.

So, again, going back to the bowtie representation, and I'll call light water reactors or large light water reactors Generation II if you're familiar with the GIF terminology, and what we have historically done, and that is we've looked at, on the core, we've looked at core damage or severe core damage as a top level event, and we've often characterized what's done to prevent it as being the prevention measures. That's things like reactivity control, emergency core cooling.

And then we've looked at how to prevent the release should that occur, and we've often described that as a mitigation measure, and that would include the ability of the containment to hold a release or to limit a release, and then siting provisions and emergency planning.

You'll see down in the various activities that we do, a primary focus on the consequences is on health effects. We'll talk mainly about that. That's like Reg Guide 1.183. How do you limit the doses to the public to below the reference values?

But then we also use it in regulatory analysis where we look broader than just health effects. This is where you start to bring in not just dose, maximum dose to an individual, but population dose, so that you can start to do a conversion to dollars and use it in a cost benefit assessment, and then the severe accident management alternatives that we look at under the environmental review that we do for licensing. So, it's used in a number of areas. It's kind of represented here. We'll talk a little bit about each one of those as we go forward.

MEMBER ROBERTS: Bill, I like this diagram, but like almost all of the defense-in-depth diagrams, there are, you know, subtleties or, you know, flaws, things that you may get the wrong view by looking at this diagram.

And what occurs to me is emergency core cooling on the left and containment on the right, like I mentioned a few minutes ago, what the industry discovered back in the '60s is that they're not necessarily independent, that if your emergency core cooling doesn't work, your containment may not work either because you need to cool the core to prevent some of the more exotic containment failure phenomena that could occur.

You know, similarly, if your emergency core cooling system worked, then you could still get what you might call plant damage because you still get potentially, you know, bloating and bursts of the clad, and app (phonetic) release out of the burst fuel rods, and maybe FFRD depending on, you know, what the burnup is in the rods.

So, you're still reliant on some mitigation even for a case where the emergency core cooling system did its job properly. I just wanted to observe that again and see if you've got any comments on that. At least I haven't seen a model yet that's perfect.

MR. RECKLEY: No, yeah, and this is an oversimplification, obviously. You have events that bypass containment, and so in that particular case, you need to come back and look and say you could get a release and the containment's not going to stop it because you have a bypass path or whatever.

So, yeah, this is a dramatic oversimplification, but by and large, when you look, it holds, you know, 80 percent of the time or whatever, so it's good for the discussion, but, you know, once you get into an actual event, you're going to maybe identify a different prevention path, barriers, or systems, and potentially even different mitigation measures.

But when we're talking big picture, and

we'll get into this a little later as well, it's often just context and understanding where you are in the conversation and what your reference point is, right? But, so often when we talk about prevention and mitigation, we talk in these terms on this slide, that prevention is to prevent core damage and mitigation is to mitigate core damage and limit the release.

But if you're talking about an individual event, then what you do to prevent and what you do to mitigate might be different than what's on this slide, but, yes, it's a good observation. You know, things are always more complicated than you're able to describe on a small number of slides.

CHAIR MARTIN: I wanted to throw in a question. One of the criticisms of Appendix D, at least three years ago, was at least the perception that given all of the different groups that are, of course, vested in understanding accident selection, there were different methods, different standards being applied, and that inconsistency is its own kind of inefficiency and potentially a safety concern.

Now, three years later, can we see that there's more harmonization of methods and standards across the different activities, environmental and, you know, the economical, the safety, the health? You know, I'm looking at the right-hand side there. I think I have an answer for you, but I'm not going to answer for you.

(Laughter.)

MR. RECKLEY: I would say there's still some differences between vendors on particulars, but in general, over time, we have standardized the approach, for example, for SAMA, and using the PRA, and how to use those dose assessments. We have guidance. The industry has guidance. It has become fairly standard reg analysis.

We have our, the NUREGs that tell us how to do that, so that's become pretty standard. Even for the top one, we have Reg Guide 1.183 for the light water reactors, and Michelle can weigh in, but I think it's pretty standard.

There's maybe more variation on the prevention side between vendors, although for light water reactors, there's many fewer vendors than there used to be, so that probably has also consolidated, but it's been a while since I've done that to be honest.

CHAIR MARTIN: I certainly feel like that the move towards risk insights and those current methods is the way to harmonize, and that's definitely been trending for a long time.

MR. RECKLEY: Okay, Anders? So, this slide is just meant, and we'll get into most of these in a little more detail as we go through the presentation, but it's just to try to show most of the considerations of where we're actually doing an assessment of offsite consequences, offsite dose, and defining a zone around a nuclear power plant that's related to that.

And so, most of us, I think, are aware, or will be at the end of the presentation here, of some of these. The exclusion area, the area in which the licensee has to have control of the property, has to be able to say, you know, give direction without challenge is the exclusion area. That boundary line for light water reactors is somewhere around half a mile from the power plant.

The low population zone, and we'll get into the connection of these to the consequence assessment as we go forward, but the low population zone, an area that should not include large towns goes out to about four miles.

The population center distance, which is the distance out to which you don't want a town of over about 25,000 people, is defined as one and onethird times the low population zone, so that will put it at about five miles.

Then historically, we've, through guidance and the regulations in Part 100, said that the population density should be assessed and be lower than about 500 people per square mile out to 20 miles. And then as was mentioned, we'll get into how that was assessed, but it included looking at severe accidents to find a value of 20 miles and a rationalization.

Todd will talk about emergency planning zones for large light water reactors. That's been around a ten-mile radius around the plant. Then in terms of our calculations that are used to assess designs, we do compare designs to the safety goals, and we look at prob fatalities.

That calculation usually is done out to a mile. And we look at latent cancers. Usually that calculation goes out to ten miles. And then when we do a cost benefit assessment, we're looking at population dose out to 50 miles. And on the right is things we'll talk about through here in terms of ongoing things that you've seen lately and some things you'll be seeing in the next revisions.

So, Anders, the next slide? So, using the bowtie, and again, looking at the prevention side, most of Chapter 15 is looking at events like increases in reactivity, decreases in cooling flow, loss of inventory, those kind of internal events that are assessed, and then systems are provided and tested against those threats or events to protect the cladding for an example.

Anticipated operational occurrences are assessed to show that you don't get a loss of cooling through exceeding departure from nuclear boiling ratios or critical heat fluxes. The loss of coolant accidents are looked at through peak clad temperature, common parameters you're aware of.

The reactor coolant pressure boundary is looked at to make sure if we have a loss of load, for example, that the pressure doesn't exceed the primary safety values. And then on the containment, Chapter 15 is looking at the challenges to the containment, the design basis accident pressure, temperatures, for example, to show that the containment can remain intact.

But as I said earlier, most of those aren't looking at offsite doses. They're looking at the integrity of the barriers. That will be used in Michelle's discussion to rationalize or justify using the approach in Reg Guide 1.183 to actually calculate offsite doses.

Then external events are largely, it's an oversimplification, but they're largely then looked -- when you look at those safety-related equipment needed in the top row, and you protect them or show they can withstand external hazards like design-basis earthquakes, design-basis floods, tornado or hurricane loads, and so forth.

The bottom we're not going to talk about today too much, but it's important from an integration standpoint and a big picture, that another set of events is malicious acts. ACRS usually doesn't get involved in security, but I put it up there in part just because there's initiatives underway to better integrate and take advantage of what's included in internal events and external events, to take advantage of that, and security by design is the term.

And so, although it's outside of the scope of the ACRS, you will start to probably see interrelationships between security and those things under your purview a little more than maybe you did in the past. So, again, this is primarily just as kind of background, but it's important to see how we build as we go to the next level, which is on the next slide, Anders. How do we actually --

MEMBER ROBERTS: To clarify what you just said on that slide, what I heard is that you use the traditional approach of picking a single event, either, you know, a transient or accident, whatever, but you've gone through the hazards assessment and concluded these are the things that are of concern, and then you credit all of the safety-related equipment to act as designed because they're safety-related and they're designed to act as designed.

And assuming that all happens, then you go through and do the analysis, which in general is intended to demonstrate that containment is not affected adversely by the transient or accident as, you know, supported by the safety-related equipment. Is that a fair summary?

MR. RECKLEY: Yeah, that's true, and for light water reactors, again, there are standards in our review guidance that's identified what events to look at, and they would not be surprising to you if you used the process hazard assessment kind of approach, again, increase in inventory, decrease in inventory, increase in reactivity, decrease in reactivity, increase in coolant flow, decreases in coolant flow, which was the kind of question you would go through to say what impact do those things have?

But by and large, that was identified in the '70s and it's been basically used up until now.

For small modular reactors, you're starting to see some of those historical things get challenged a little bit. They don't quite work, so there's been variations taken. You've seen it in things like NuScale reviews where some of the traditional approaches might not work or can't. If you don't have large bore piping, it's hard to have a break of a large bore pipe, right.

MEMBER ROBERTS: The reason I asked is what gets confusing is like Reg Guide 1.183 uses a severe accident release as the driving function or source term, and I think it's probably important to understand going in that's a conservatism in your approach, that if you actually had the postulated event from the hazards assessment, you know, mitigated or whatever by the safety-related equipment that was designed to mitigate or prevent core damage, you would not have the severe accident release in the first place.

And so, to talk about a severe accident release being the purpose of Reg Guide 1.183 would be a misnomer, and it's really a question of defining enough conservatism to be satisfied that the analysis is conservative once you get out the other side.

MR. RECKLEY: Right, and we'll talk, and when we talk about the defense-in-depth, the traditional approaches to containment is one of the barriers or measures for defense-in-depth. We talked about the history. Again, this has evolved over many decades. You need to keep in mind, and I'll forget the number, but --

PARTICIPANT: We know what you mean.

MR. RECKLEY: When that was written in 1960 to test the containment, almost go back in your mind as to what the analytical capabilities were in 1960. You didn't have computer codes that could start with an event and run it all the way through a release. You had computer codes that could do a subchannel analysis in the core, maybe a plant-level response of the coolant system, and then the containment.

And so, one of the reasons they were done that way was because that was what was possible when the methodologies were developed, but as time goes on, we've modified them and we've brought in things as they've evolved like PRA and so forth, and better computer codes.

MEMBER ROBERTS: Right, I might also

suggest that in the 1960s when the TID was written, that was before there was this understanding that the containment function was tied to emergency core cooling. And so it was not that surprising to assume you had a, you know, unterminated loss of coolant accident with the containment terminating, you know, blocking the release to the public, which became less of a good assumption when the realization came that they weren't necessarily independent events.

And that's part of my line of questioning is starting in about 1968, it wasn't clear why you would assume, you know, a severe accident kind of release coupled with containment functioning, and so the rationale if you're testing the ability of your design basis systems, your safety-related systems, you're going to terminate the event and prevent the release, and that makes sense.

If it's like the TID and you had the unterminated loss of coolant accident, but containment, you know, stopped the release to the public, that doesn't seem like as good an assumption, and probably hasn't been for 50 years.

MR. RECKLEY: Exactly right. I mean, all of this stuff has evolved over the decades, right? I mean, this model for Generation II plants assumed diesel plants work, because all of the systems, reactor coolants, emergency core cooling systems, containment, protection systems, they all took AC power.

Well, as we learned more, that started to be questioned and we looked, but yeah, and again, it's an interesting discussion because these topics, you know, they've evolved over the many decades that we've been involved in this, and we made adjustments in certain places. Anders, next slide if you would? So, getting off of Chapter 15 --

CHAIR MARTIN: Just a real quick time check to get a better feel for how far behind we are.

MR. RECKLEY: Well, this part is going to take longer, the first segment. The middle segment, again, largely will take as long as you guys want. It is really a summary of Revision 4 to Reg Guide 4.7, which came through your committee. Many of you weren't here then, but it came through the committee, so that part will go faster.

CHAIR MARTIN: You feel like we're okay?

MR. RECKLEY: We're probably behind, but that's -- Michelle doesn't talk as much as me, so she'll go faster. So, that does get us then into Reg Guide 1.183, the design basis radiological consequence analysis, and what we've talked about a little bit up to this point.

For that accident, you are assuming a major accident, a core melt type of accident. Michelle will talk about that a little bit more. That puts a source term in terms of the timing and mix of radionuclides into the containment.

The containment is modeled to leak at a certain amount at the pressure that the accidents impose, so it's, you know, what will the containment leak when it's at 40 or 45 pounds of pressure from the accident? And that number is usually on the order of one quarter of one percent of the volume of the containment per day, and then tests are done to make sure that that is a conservative leak rate for the containment.

So, it's tested, but then that leak rate is used for the analysis that Michelle will talk about, the dispersion and ultimately the comparison of the doses at the exclusionary boundary and low population zone, to show that the dose is over the given period of time at those distances is less than the references values.

MEMBER ROBERTS: Just to jump in again, you used the term core melt accident, which is, I think, right out of the regulation, but I think that's confusing and it's probably good to again reiterate that if you had a core melt accident, at least based on our current understanding of severe accident progression, you're going to challenge the containment leak rate and that probably won't be the leak rate you have.

So, what the regulation I think literally says is the release assumed from fuel is based on a core melt scenario, which means you've got kind of a mix of scenarios. You've got a very conservative release from fuel for a case where you're modeling your engineering safety features are functioning properly, but then you then assume that the engineering safety features do function from that point forward.

So, it's kind of a left hand, right hand. You're making assumptions from both sides of the table, that you're assuming that you were unsuccessful in preventing core melt, but then when you look at the containment function, you assume you were successful at preventing core melt. Is that right?

MR. RECKLEY: Well, you're assuming that containment will perform in terms of the leak rate at the temperatures and pressures that's resulting from the large break loss of coolant accident generally.

This is one set of analyses, and then we'll talk later about another set of analyses where we used different assumptions to make different decisions, but for now, this is the approach for the Reg Guide 1.183 analyses for the dose to individuals at the exclusionary boundary and low population zone.

MEMBER ROBERTS: Right, I think you said it's on a subsequent slide, so I guess I'll wait for that.

MR. RECKLEY: Right.

MEMBER ROBERTS: But there's no physical meaning you can attribute to these numbers? They're simply figures of merit that come out of the analysis?

MR. RECKLEY: Like 25 rem and --

MEMBER ROBERTS: 25 rem around the EAB or LPZ boundary.

MR. RECKLEY: Michelle's got a better history, but they are reference values. We make very clear in the regulations that they're not a radiation protection standard, but they are numbers that have been used historically to see if the design can limit the releases to below those reference values when combined with site features.

MEMBER ROBERTS: Okay, so maybe we'll come back to this, but this is also a comment we made last year in a letter on the Reg Guide 1.183, that it would be good to have something written down that explains this apparent inconsistent assumption of the core melt drives the release, but then containment is assumed to be intact regardless of what physical phenomenon. If you have core melt, it might affect containment. So, if we need to come back here, but I think we'll probably visit it next month when you talk about --

CHAIR MARTIN: Yeah, yeah, I wanted to mention that just for the record, that -- is it both November and December we get to talk about Reg Guide 1.183? I'm looking at Michelle because --

MEMBER KIRCHNER: I think the schedule is coming up, yeah.

CHAIR MARTIN: Right, right, so I think we'll certainly have plenty of time to dig into it, but it's a good warning for Michelle.

(Simultaneous speaking.)

MEMBER KIRCHNER: Tom, I would go back and just say that, you know, in 10 CFR 50 and then 52 picked up the same terminology of a maximum hypothetical accident, that was used to set a bounding source term without talking about how well the preventive systems functioned, and then you entered the analysis on the previous view graph and you're correct. In some of those cases, there may be an actual challenge to the containment.

But I think my recollection of the history is this would be a conservative bounding assumption, and now let's see how a designed containment would function as Bill said, with the leak rate that's about a quarter of one percent per day, and then you go ahead and do the siting analysis.

So, it was nothing that was acceptable about this. That was not a goal to get 25 rem at the EAB for two hours. In fact, there's language in the -- there's a footnote to the language in 50 and 52 that suggests it should be well below that, but for purposes of doing siting analysis, I think historically that was a way to come to this next view graph.

MEMBER ROBERTS: Right, I agree with that. The way I look at this is a different defense-in-depth model that's coming up later in the slides is the IAEA Five Level model.

The assumption of a melt-type release coupled with containment function is a very conservative way to assess Level Four of defense-in-depth, which is you're looking into building your engineering systems to prevent the casualty or prevent it from getting worse, but when you get to Level Five of defense-in-depth, that's failure. So, now what do you have to go and assess that against? And we'll talk and you'll hear about emergency planning and other site population considerations.

We're not suggesting that the 10 CFR 100 criteria really don't fit in a Layer Five of defense-in-depth thought process because the assumption has already been made that the engineering safety systems work, and so when you look at a Layer Five here, that's where everything has failed.

So, it's just important to keep in mind that this assumption that containment meets its requirements regardless of design assumptions rather, regardless of what the phenomenology might predict, you know, I don't think that's what this analysis actually does. I think it's actually a very conservative source term for assessing design basis systems. That's why I wanted to give this clarification.

MEMBER BIER: Yeah, one other comment. This is Vicki Bier. I think, you know, some of the things we're discussing are kind of details of the policy or the standards here, but I think at a high level, the general idea makes sense. I mean, one of the things we've seen unfortunately in the last years is that it's really hard to do evacuation of a huge population, you know, if you're talking about Katrina or that kind of level where you're evacuating hundreds of thousands of people. It's difficult to do that well, so things like the low population zone are kind of just practical strategies to avoid that situation is possible, so.

MEMBER ROBERTS: Right, and I would argue the problem with that is the low population zone is calculated with the assumption the containment works.

MEMBER BIER: Yes.

MEMBER ROBERTS: And so, what you get is what would -- if you're really looking at the worst case scenarios and you're ready to evacuate a population, that's not the population you'd be worried about. It would be a much larger population because the real event, you know, presumably would have had a containment, you know, failure in it, an event that would actually trigger a mass evacuation.

And so, that's where the 20-mile radius in Reg Guide 4.7, that's where it asks questions about these LPZ and population center distances, their adequacy and, you know, predicting the ability to deal with those kind of events. But yeah, I think that's one of the key points here is what analysis supports those types of events? Because it doesn't seem to be the Reg Guide 1.183 analyses, which make that, you know, assumption that the design basis systems work.

This is an important layer of defense-in-depth. You want to know if your design basis systems do their job, and you hope that -- not hope. You have engineered the systems. You have a very, very low residual probability of getting to where Layer Five of defense-in-depth matters at all.

And so, you want to have that low probability, and then you want to have an understanding -- you do have capability for Layer Five of defense-in-depth commensurate with the likelihood of getting there, so that's kind of, you know, where I look at this whole story of the siting analyses is they don't seem to be really oriented towards supporting that.

(Simultaneous speaking.)

MEMBER ROBERTS: -- history that Bill didn't get to because we don't have three and a half hours, but if you look at the NUREG-0625, the 1979 document, that's a good read because that was the culmination of a team of NRC staff saying we have the wrong criteria in Part 100, and they were for various reasons unable to get them changed, but there were other reasons that drove that, but it's important to understand the limitations of those criteria if you're really looking at mass evacuation kind of events that are not impossible.

MR. RECKLEY: And what you'll see, and we'll get to it in some of the later slides, is -- I agree with the conversation. This is done for the purpose it's done, and it we stopped here, then there would be criticism that we stopped in an inappropriate place, but we have the severe accident policy statement that goes beyond this.

We have the population density controlled out to some distance to help control this. We'll get into emergency preparedness later. There are a number of things, the safety goals, the inclusion of probabilistic risk assessment that has been more incorporated into our decision-making, so all of those things are added to this assessment, right.

But with that, I'm going to skip slide ten because it simply repeats the table from earlier in terms of what the zones are. Then I'll just touch on the population density. We're going to talk about that more in the second session since it is the topic.

But as Member Roberts said, this also has a long history. Should it be ten miles, 20 miles, 30 miles, 40 miles? All of that was assessed in the decision that was ultimately made in the Part 100 rulemaking that it would be 20 miles. The rulemaking was in the '90s. It took a long time to do, but that assessment went further than what we just talked about in terms of Reg Guide 1.183. It did consider severe accidents.

Now, at that time, that was a reactor safety study. You know, if we were to do it now, we'd have more data. We'd have SOARCA, and NUREG-1150, and other sources of data, but when that they did this assessment, it was largely a reactor safety study, other assessments that they did.

Then in regulatory matters, it's not all just the math, right? We went out and got public comment on what the distances were, and some said it should be larger, some said it should be smaller, but that's part of the decision-making is not just doing the calculations and saying oh, there's the number.

It's going out, soliciting public comment and feedback, and considering any number of qualitative factors, keeping in mind by this time, there were a fair number of operating nuclear power plants, right, so that's playing into the decision-making as well.

So, all of that went into play. We had a generic analysis that basically said 20 miles is a reasonable number. It's not something you can prove or derive through a calculation. It's a reasonable number and that's what we've lived with since the rulemaking.

Again, there was a period where it was 30 miles, but for the last many decades, it's been 20 miles based on that generic analysis, and we'll get into the second session where we're now saying we're going to offer an alternative to that, but require analysis to test it by. So, we'll go to the next slide, and I'll shut up, and Michelle, you can make up for all of the rambling.

MEMBER HALNON: So, Bill, before you go, I mean, what you just said, this has no analysis to it, that you're going to offer an alternative that requires an analysis. How do you equate those two? How do you do an analysis to prove that something you never did an analysis for in the first place was --

MR. RECKLEY: And that was really a trick. And that’s why we had to send a paper to the Commission. This is a policy issue. You have to weigh in on --

MEMBER HALNON: It gets back to the policy.

MR. RECKLEY: -- the criteria. And we did look at some of, I won’t say equivalency, but what did generic analysis do? And we have to do something similar. Plus, we’re now better informed. And it’s 30 years after that work was done.

MEMBER HALNON: Better informed in a couple places. One is we were tainted by the assumed, if not informed safety of the large light-water reactors. That was all we had, except in the test reactors. We even had different regulations.

Now we have advanced reactors, which are much closer to the test reactor safety levels than the large light-waters. And our mindset has to change. So, I’m worried that we have to do an analysis to show the thing we never did an analysis for is --

MR. RECKLEY: No. No, I understand. It's not lost on us, right, that the generic analysis set 20 miles. But what we were hearing from stakeholders, including the Department of Energy, who has been doing plenty of studies about what was the impact of keeping 20 miles would be -- and Oak Ridge. A time I know came when we were going Reg Guide 4.7, part of the thing to keep in mind -- again, you need to do public safety, but the keeping of the 20 miles, they did studies. And one that comes to my mind was around Kansas City. You know, nuclear plants replacing fossil stations. If you kept 20 miles you eliminated all but maybe one or two of the retiring fossil stations around Kansas City when they did that study.

So, the general thought was we need to have an alternative to 20 miles. And now we can use analysis, was the assumption. And that's, again, we went to the Commission with a policy statement and finished the guidance --

MEMBER HALNON: I'm waiting for the rest of the story.

MR. RECKLEY: All right.

MS. HART: So, good morning. I'm Michelle Hart. I'm a senior reactor engineer, and I'll be talking about Reg Guide 1.183. I'm not in charge of the review or the revision of it. I am part of the working group as well.

We've talked a little bit about the history. I won't rehash a lot of this. But, you know, originally the large light-water reactors currently operating were all licensed under a version of Part 100 and the TID-14844 source term, which assumes release of 100 percent of the noble gases, about 50 percent of the halogens, and one percent of others, is the way it's talked about in the Reg Guide.

TID-14844 was developed and is kind of the technical basis for Part 100 as originally issued. The figures of merit, the dose criteria for determining the emergency planning -- I mean, not emergency -- excuse me, the exclusion area boundary and the low population zone was dosed to an individual over certain time periods, and they were whole body and thyroid doses. It was 25 rem whole body, 300 rem thyroid.

These Reg Guides and the NUREG-0800, the SRP, discussed the assumptions and analysis that you would do with that is not an integrated analysis, as we have been talking about. There's -- and I think I agree with Member Roberts' characterization that it's a large source term to look at the containment capability if you assume that it operates at the design basis capability of the containment.

Next slide, please. So, we have moved on to Reg Guide 1.183. The original revision of Reg Guide 1.183 was based on NUREG-1465, which is a severe accident source term. It's more than one severe accident. There's a set of different events that they used in all of these that's to meet the general idea in the fission product footnote, which has words like has generally been assumed, and is postulated for purposes of siting, or not to be exceeded by any accident considered credible, those type of words.

Generally has been assumed to be a core melt. In NUREG 1465 it was still a core melting event. It involved a whole core and was similar-ish to TID-14844, but the timing did change. We had a different timing of the release. And the noble gases were still 100 percent. The halogens were about 30 to 40 percent. There were differences for BWRs vs. PWRs. And the speciation of the iodine changed so that it was mostly particulate instead of mostly gaseous, so then there were more removal mechanisms available if you wanted to model them specifically.

The dose criterion, the figure of merit, did change from full body and thyroid to total effective dose equivalent, or TEDE. It was then determined to be 25 rem. There was a argument at the time that was approximately risk equivalent to the previous criteria. I think it's not exactly correct to say that. But I think it's a reasonable, much less than would cause any kind of health effect to persons offsite, if they would exceed -- if they would receive this dose. As well as the criterion is looking at an individual in the center line of the plume for the duration of its passage at the low population zone, so it's not realistic assumption to assume a person would actually see that type of dose.

At the EAB it's for the peak two-hour period instead of the first two-hour period to accommodate that difference in timing for the release.

And so this criterion is one that we would use for any new reactor moving forward, would be the 25 rem TEDE. We would no longer use the whole body and thyroid for a power reactor. Test reactors still use that criteria.

Next slide, please. So, these are the criteria that we currently use. I mean, I've just described this. There's also a criterion, a design criterion for the control room.

In Appendix H, Part 50, are the general design criteria for generally applicable for light-water reactors, may be used as guides for the principal design criteria for other designs. And in that case there is a control room radiological practicability criterion that is 5 rem TEDE for the duration.

Next slide, please.

MEMBER HARRINGTON: Is that individual cumulative dose?

MS. HART: So, it's the dose to the individual operator. So, in Reg Guide 1.183 and also in the standard review plan we do have different criteria for the non-LOCA or non-maximum hypothetical accidents. And they are generally graded based on a qualitative likelihood. There are no specific frequencies given, and they are the same for each reactor.

We haven't had discussions with anybody about changing the criteria. And there are three different levels for the maximum hypothetical accident, the accident that's described in the footnote to the regulation. It's the full regulatory dose value, 25 rem TEDE.

It's also applicable to some other or the non-LOCA design basis accidents that have a lowest likelihood of occurring among the ones that we need to look at.

There's four I call it low relative likelihood, kind of the middle range. There's the criterion of well within our 25 percent of the dose criterion of that 6.3 rem TEDE, is the way we noted it in the Reg Guide 1.183.

And then for those with the highest relative likelihood, it’s a small fraction of or 10 percent of the dose criterion, that 2.5 rem TEDE.

And the general idea is, you know, the more likely the event is to occur, the lower the dose criterion that you would need.

MEMBER KIRCHNER: Michelle, just to probe a little bit. When you actually evaluate an application, how do you see yourself using this table?

MS. HART: So, in the case of light-water reactors, which this was developed for, you already have the accidents laid out in the SRP. So, everybody generally follows that.

MEMBER KIRCHNER: Right.

MS. HART: Now you can have discussions about this with a small modular reactor. You know, one of the events that gets the well within criterion, 25 percent criterion, is the fuel handling accident. And that’s compared to the steam generator tube rupture that, you know, they have the same dose criterion.

Are they really the same likelihood? And a steam generator tube rupture occurring when you’re at the 48 hour maximum tech spec coolant activity gets the full dose criterion.

So, you can see that the fuel -- I mean the steam generator tube rupture at the normal coolant activity is much more likely to occur than one that's at the 48 hour maximum coolant activity.

But can we compare the fuel handling accident to the other, like, the steam generator tube rupture or main steam line break and say that they're equivalent or not?

I don't think that there's, there's a good way to really move away from the criteria, as we have set them up, in specific, you know, quantitative way. There's more of a, you know, this was a decision made back in the '80s or '70s kind of thing, and so how do you move away from that?

And we haven't had discussions for those. I know that seems rather unsatisfying. And it is kind of unsatisfying. But I think if you compare this to, like, the frequency consequence target that we're using with LMP and with PRA, I think it's a lot more structure and it's easier to see that the criteria and the frequencies how they, they line up.

Next slide, please. So, as we note, in Reg Guide 1.183 none of the DBAs, including the maximum hypothetical accident are intended to be actual event sequences were intended to be surrogates for those to enable deterministic evaluation of this plant safety-related work.

And, specifically, the accident release mitigation features, not prevention or core damage or things like that, it's more focused toward those things that would contain or retain fission products or other radionuclides.

They're intentionally conservative in order to address the uncertainties in accident progression, transport, and atmospheric dispersion. So, we do these, traditionally, these analyses have taken deterministic not necessarily integrated, you know, the same types of, you know, it's not an integrated analysis.

You take just conservative assumptions in these to try to maximize the potential consequences offsite but, at the same time, also evaluate, you know, giving them credit for the safety-related systems.

And so, some of the conservative assumptions are these 95th percentile meteorology, the dispersion could only be worse 5 percent of the time based on site-specific data.

There's no protection act -- no protection actions that are credited in these analyses, no dry deposition, or sheltering, or, you know, weathering or any of those kind of things.

At the same time, you're only looking at the consequences of the plume passage, so you're not looking at ground shine or anything like that as well for these types of analyses.

The source term is risk informed now. But the Reg Guide 1.183 we have used more of today's evaluations to determine the maximum hypothetical accident. There are more recent studies have you seen -- as you've seen in Revision 1 to Reg Guide 1.183. And an even newer revision in the Revision 2 that you'll be hearing about in conjunction with the increased enrichment goal making activities.

And in those cases what we mean by risk informed is you look at all of the spear accidents, potential accidents that would result in core melting, or core-wide damage, maybe not necessarily melting. And you take, you know, you develop a source term that would be representative of those type of events.

The modeling does generally not credit facility features that are not safety-related, as we've discussed.

If they're not covered by technical specifications we generally don't model them. If they don't meet single failure criteria, or if they rely on the availability of offsite power. Any delay should be credited. So, you're looking at how do these safety-related pieces of equipment really work to negate potential releases.

CHAIR MARTIN: A clarification. When you all visited last fall, mentioned you had been at Sandia, right, in the presentation as well. Is a newer document for Sandia 2023.1313, I thought it was updating a 2011 document, or what is that? You didn't put it on your slide, I wondered if --

MS. HART: No.

CHAIR MARTIN: -- that's intentional or?

MS. HART: No. I'm referring to the documents that are currently guidance that is out there now. So, the newer guidance or the newer Sandia report is not being used for licensing yet. And that's part of the process of going through the process of going through the review.

CHAIR MARTIN: Thanks for that clarification.

MS. HART: So, I know I went through that kind of quickly. It's kind of high level.

Is there any additional questions?

MEMBER KIRCHNER: Just an observation,

Michelle.

But there still would be a second simple, there are source term, you're still postulating a failure significant event?

MS. HART: Correct.

MEMBER KIRCHNER: We're not seeing that on LWR designs.

MS. HART: In the context of the evaluation of the siting criterion, or the 15.34 safety analysis that you would do, the design basis accident analysis, I think it's too early to really say that nobody will do that. If they're using the licensing modernization project process for the PRA, they are not required to develop a, you know, a bounding analysis or anything like that.

They may choose to.

I think there's some issue with how you deal with the language in the regulation. The regulation itself says you have a release of fuel into the containment, you expected demonstrable containment leakage rates, and then the meteorology. And then there's the fission product footnote.

So, does what you're proposing for your facility as a non-light water reactor meet all of the or conform to that kind of language? That's a discussion we would have to have.

MEMBER ROBERTS: This is the slide I was thinking of for broader response initiatives, the slide that says you shouldn’t really take any meaning to the numbers. That’s not quite what this says, but again, that’s essentially what this says.

But just wrapping back around to Vicki’s question from earlier, this is a very conservative analysis for what it does. Is there any way to correlate to severe accident scenarios? Or is that just beyond what, what’s been done?

You took an LPC of four miles, I think you had. Could you draw any conclusions about that evacuation zone or is that just a completely, you know, different question?

MS. HART: I think because it’s not really an integrated assessment it’s hard to make that correlation.

MEMBER ROBERTS: Okay, thanks.

Then the other question is population -- this just wasn’t on the previous slide -- but the 1962 rulemaking document said that the analyses to date show that a population center distance was a reasonable surrogate for severe accident performance.

Has there been any work in the last 60

years to, you know, confirm or refute that?

MS. HART: So, when we went through developing the SECY paper for the discussion of population-related considerations, I think we did look at some of the historical information on that. And I don't know that there were any quantitative evaluations that we've done.

Bill, do you have any more information on that?

MR. RECKLEY: No. We decided at that time that we weren't going to pursue rulemaking to change it. One-and-a-third is in the rule.

Now, you can look, Michelle, -- not calibrated here -- but, you know, if you're at 25 rem, you know, and just do the power entry you're going to be -- you could get a rough estimate of what you're going to be at one-and-a-third.

And but the primary, primary driver was we decided not to pursue a rulemaking. So, one-and-a-third remained.

Or, again, the 1979 NUREG, their recommendation was to delete the population center distance put it in Reg Guide 4.7 in the regulation. So, that's where they were, essentially were 45 years ago.

It seems like I guess my observation is there's no real correlation between these three criteria out of, out of the Reg Guide 10 to 100 and actual live emergency response or expectations for how you would actually deal with an event.

MR. RECKLEY: So, Todd in the next few slides will start to talk about the emergency of various aspects.

But a lot of this ties to a general Commission policy to locate reactors away from populations; right?

And so, that's why it remains sort of maybe less satisfying for people who want an equation to show how we, how we got here.

MS. HART: And, of course, the regulation does use words like generally low populations, and generally away. And so, that's why I think a lot of this guidance, you know, lies in the Reg Guides. You know, like the population density is in the Reg Guide. It's not in the regulation.

But, you know, as a very vague proxy for societal risk, or a very vague proxy for capability of taking action, I think that is maybe the intent. And maybe I shouldn't have used the word vague, but it's there's not a specific criterion or specific numerical value that's been put on these things that we just discussed.

MEMBER PETTI: This is Dave. Michelle, I wanted to follow up on Walt's question on the severity of accident. It's called the maximum critical accident. When you think about advanced systems, it seems to me that LMP, they offer an avenue where the severity of such an event is less based on frequency arguments than, you know, the historical deterministics, taking an event which is what our light-water started.

I think that's what's somewhat unsettling to think that there will be this dichotomy, if you will. I mean, actually the question to ask yourself is if you're in an LWR, LWR through LMP, what would be, you know, those design basis events from which, you know, you can go forward on the source term? I mean, would it be what was postulated in the regulations or not?

MR. RECKLEY: And the answer is probably not.

MEMBER PETTI: Probably not. Right? Yeah.

MS. HART: And, with that, my time with you is done. And I will now pass over the presentation to Todd Smith.

MR. SMITH: Great. Thank you, Michelle.

Good morning. I'm Todd Smith, Senior Level Advisor for Emergency Preparedness and Response. And what I'm going to do now is give you a very high level overview of emergency preparedness and some insights on how do we use these risk insights to inform the plan.

Emergency preparedness is an operational program. It's all about taking action. For NRC to issue a license we need to make a reasonable assurance finding that protective actions can and will be taken. EP is the final layer of defense-in-depth, and it's an independent layer. So, EP and EPZ are not part of siting or design. EP has its own criteria that have to be met. And these criteria give you capabilities to provide dose savings.

Now, here is where we're going to see some difference in the character in the EP regulations from siting and design. Michelle just talked about figures of merit that we use. But in EP there is no -- an active plan does not achieve some minimum dose savings or some minimum evacuation time. The concept is reasonable and feasible dose reduction under the circumstances.

For this, we are risk informed. We need to understand what are those circumstances in which we may need to act.

A lot has to do, though, when we start talking risk informed performance-based EP. We can confuse terminology of what we mean in design. For example, usually when we talk risk in EP, we are not talking risk triplet: what can go wrong, how likely is it, what are the consequence? Usually when we say risk, we mean radiological risk or dose.

Go to the next slide, please. The good news for EP is that we've always been risk informed. We're very adept at it. In the NRC we call this our graded approach.

We license many different types of facilities with hazards and risks. Some of them have planning zones that support the finding, some do not. They all have effective emergency plans.

But there's two key points I want to emphasize then about planning. The first is it needs to remain flexible. The idea behind planning is you have some core planning that you can respond to any event, including very low probability of accidents.

The second concept behind the planning is it's not all based on quantitative analysis. There's a lot of qualitative assessments that have helped inform planning. And we use a lot of judgments.

Can we go to the next slide? So, taking those two points, I've tried to illustrate that in this slide here. In the quote that was up there in the last slide it talked about margins of safety. What does that mean really in an EP context? Do we really talk about margins of safety as we would in design?

When I'm in design space I can talk about margins of safety between operating limits and failure criteria. But that doesn't really translate into EP.

In EP we're not even there until we've exceeded those safety margins. So, what I'm trying to illustrate here in this figure is how is it that we arrive at that core planning that meets the regulatory requirements?

So, the core planning is represented by that orange line. And what I'm showing you in blue and red lines is how do factors like likelihood, consequences inform planning?

Certainly we want to make sure we have plans in place to deal with more likely events. And as you start to develop your plans you find that you've developed capabilities that are adequate to address even more very unlikely events.

Similarly for consequences, if there’s very low consequences you don’t need bunches of planning. If you’re consequences increase, you need to add for capabilities. But, ultimately, you get to a point where those same capabilities can be applied to even more severe accidents.

And so, the key point here is when we say risk-informed performance-based EP, we’re not necessarily talking risk-informed performance-based design.

Go to the next slide, please. Formerly we accomplished this through the planning basis concept that goes back to the 1970s and NUREG 0396. A key point about this is though it’s not unique to NRC regulations, the idea of using a spectrum of accidents shows up in other countries, in IAEA safety standards. They call it the hazard assessment.

The concept is that you use a spectrum of accidents to understand the distance time material to scope the planning efforts. This concept, distance time materials is very simple. It sounds a lot like time distance shielding we use for radiological protection. So, it’s a very powerful, very simple concept but it shows you what is it that we need to know in EP to be able to scope the planning efforts.

Chairman Martin, your question came up earlier about efficiencies. And part of our transformation efforts in EP, like when we issued 5160, was to recognize that a lot of the information that's needed to inform the planning is developed in other parts of the licensing basis. And so, the rules and guidance provide for that efficiency by making use of licensing basis events, how you're treating security, environmental reports, in scoping the planning efforts.

MEMBER HALNON: So, Tom, this is Greg.

MR. SMITH: Yeah.

MEMBER HALNON: On events where it was the fact that EP is not depended on. You said earlier that if it's independent of all the other stuff that goes on, how does that square up?

MR. SMITH: Because we use that information to inform those capabilities. But the capabilities themselves are independent of any accident probability or likelihood.

I'll give you an example. Communications capabilities, I may have a system in place, you know, a phone line, dedicated phone line to call all sites. But recognizing there are events, like station blackouts, I will make sure I have some backup that's independent Office of Administrative Law Judges the main power supply to those communications.

MEMBER HALNON: So you're going a step further then with that sort of what if?

MR. SMITH: Correct.

CHAIR MARTIN: So, to make judgments you would have to be able to test the premises; right? With regard to emergency preparedness or anything related to safety, ideally you start with a benchmark, and then you need to perform your tests.

So, you know, the easiest way to look at, you know, any of these questions of radiological safety is to consider something we might call unmitigated outcome, unmitigated event. You know, you want to pull back on the history lesson, right, you have WASH-740 in the '50s, right? Basically you had no containment and it postulated rather serious consequences.

Subsequent to that, we layer on the defense-in-depth philosophy, et cetera, et cetera, and we can begin to quantify the benefits of all the features, safety features, et cetera, et cetera.

I think what we do, we say Reg Guide 1.183 is -- doesn't necessary have a true unmitigated event as you might have with a WASH-740, but you have a serious event. And you can still test; right? You can still quantify, you know, whether it’s any kind of mitigating procedure, you can indicate whether it’s an administrative procedure or performance of structure system components.

Really, that is what is important here is being able to demonstrate that you can improve the situation. It’s generally skiing along until things break, of course. But isn’t that the idea, really? If you need a benchmark and so you can test and you can -- you know, the devil’s in the details. And that’s -- you’ve got to begin somewhere.

MR. SMITH: Absolutely. And that's the heart of risk-informed EP, is that -- we could spend all day -- you know, I could give you lots and lots of presentations to show you this, we do test it and we do challenge those assumptions and we do look to find how can we use the risk insights to enhance the dose savings that we get from EP.

A lot of this you won't find, though, in PRAs. We do get insights from studies like SOARCA, we will get insights from the Level 3 PRAs. But I just brought one example -- a couple of examples of studies that we do, right, where we look at, how do we quantify the benefit of emergency preparedness and test those things against, you know, how would this hold up under, like, severe seismic events --

CHAIR MARTIN: Real quick, for the record, what did you just show us?

MR. SMITH: Yes. For the record, this is the study of emergency preparedness significance quantification process proof of concept, NUREG/CR-7160. And, of course, NRC, we've studied evacuations for decades. We know they're effective. We know they save lives. We know the conditions, the planning that are required to ensure you have effective evacuations.

We also recently looked at, how do we better use shelters. So, again, I'm very much outside of plant, right, and I'm looking offsite and I'm looking at the actions that the public's taking. So the risk-informed decision-makers of the public after they go offsite. And we recently just published a new study that looked at insights on how can you better use heating and air conditioning systems in emergency situations to control the indoor air contaminants to reduce the exposure.

So, we do a lot of science behind that and we've given a lot of talks at the Regulatory Information Conference and at the conferences we go to, how do we enhance emergency preparedness through science.

MEMBER BIER: Another question. This is Vicki Bier. Something that I probably should have researched ahead of time, and didn't think to. Can you talk about what provisions are made for emergency response for people who don't drive or don't own a car? Because that was a huge issue after Katrina. We're obviously not talking about, you know, transit-dependent urban areas here, but what has been done about that?

MR. SMITH: Yeah. So, from a regulatory requirement, licensees have to develop their evacuation time estimates, and those ETEs consider transit and transit-dependent populations, special populations like hospitals and schools. And the analyses then inform the offsite planning and the capabilities and resources that they need for protection for those demographics.

We also -- as I mentioned, we don't rely just on evacuation. Another study I'd like to point out, NUREG/CR-7285. We examined, what are the non-radiological health impacts of evacuation relocation. A lot of lessons learned from Fukushima, okay? So, you don't necessarily want to rely on a precautionary approach. And this is why we're so interested in the effectiveness of shelters because not everybody can get in a car and evacuate, but that doesn't mean that it can be any less safe by staying at home.

We're even looking at quantifying the effectiveness of wearing a mask. So COVID demonstrated people are acceptable -- comfortable wearing a mask. We're quantifying and working with our colleagues in research, you know, what benefit does that give you in terms of inhalation dose savings, what's the tradeoff for the skin dose, and we're finding a lot of benefit which we're quantifying and then we're going to use to update some guidance.

PARTICIPANT: Which is what, cleaning your filter every six months, and --

(Laughter.)

MR. SMITH: Yes, and using standalone filters.

PARTICIPANT: Right.

MR. SMITH: The key is, the EPA's protective action guide manual, which provides the guidance to state and locals, recommends doing this, recommends putting a cloth over your face, recommends, though, shutting off the HVAC. What we're trying to do is get better nuanced guidance with real quantitative data to back up those assumptions. When we tell the public, this is safe to do this, it's backed up by our science.

MEMBER BIER: Because I think, even in rural areas where the vast majority of people drive, there are always going to be, kind of, elderly folks who aged out of driving who depend on their neighbors to bring stuff in for them or whatever. So I'm glad to hear that that's being reviewed.

(Simultaneous speaking.)

MR. SMITH: Yeah, we're trying to get the more risk-informed decision-making.

MEMBER ROBERTS: Following up on Greg's question. If you use a frequency-based criterion to screen out accidents such that you conclude your EPZ is the site boundary, what kind of infrastructure do you not have in the community that you would have if you did have an EPZ that went beyond the site boundary?

MR. SMITH: Actually, very little. You know, even going back to the 1970s when they were asking the question for NUREG-0396, you know, what distance should we plan, it wasn't a question of, we don't have capabilities to evacuate, it was simply the distance, right? So, there is a lot within all-hazards planning of capabilities to evacuate people. We see this all the time. I mean, look at Hurricane Helene right now. Okay, there was no emergency planning zone but we had evacuations to save lives. We saw this with the train derailment last year in East Palestine. So, a lot of capabilities --

MEMBER ROBERTS: Okay you're not there yet but a couple of a slides from here has a plot from NUREG-0396, and I've interpreted it as an evaluation of the effectiveness of the EPZ. I think you'd probably disagree with that characterization, that it's really just an analysis of what protective measures would do regardless of whether or not there was an EPZ. I was wondering if you could comment on that. It's slide -- I think it's slide --

(Simultaneous speaking.)

MR. SMITH: Yeah, let me -- that's my next slide, but let me make one more point, here. Because there's another key difference between our current regulations for large light-water reactors and the risk-informed performance based regulations in 5160. And that is, who does the hazard assessment. In the past, the NRC, we did the hazard assessment through the planning basis, and we scoped the planning effort.

So regulations are prescriptive but

they're no less risk-informed. So, under the new regulations, the applicant will do their hazard assessment to scope the planning efforts. Can we go next slide?

Yeah, so -- shut my mic off. And the key thing about the regulation is that it's giving the applicants the same flexibility to make risk-informed decisions that the NRC has made in the past, and that includes scoping the emergency planning zone. The first thing to recognize about the emergency planning zone is it's not a design feature, it's a planning tool. It's meant to help implement pre-determined -- protective actions.

And NUREG-0396 didn't necessarily lay out, you know, the definitive way to approach sizing an EPZ or determine it, right? What it did illustrate is the utility of the risk-informed approach and how you can use multiple lines of reasoning to align at a reasonable result, okay? So, at the time they used the available information they had from design-based accident criterias, the risk insights from the WASH-1400 reactor safety study, their understanding of environmental reports.

And then this, also -- this study that was done at the time of, what would be the efficacy of different protective actions within, you know, certain distances from the facility. And this brings up the key thing to understand about the emergency planning zone, then. If you look at that middle graph, the green line, okay? What that's telling you is, the EPZ is not a boundary beyond which I cannot exceed a dose. It's a reasonable distance for the planning.

The assumption is, if there's an accident, I may not have to take action within the entire emergency planning zone but I also have capabilities to take action beyond it as conditions warrant. And that concept of the emergency planning zone is carried forward today.

MEMBER ROBERTS: Right. Yeah, my question had to do with the right-hand plot where, what that's telling you is that if you do something from a protective response standpoint and you reduce the number of fatality, I think, is what this plot is, by a lot. But, obviously, not down to zero, which is your point, but down by a lot. And the question is, does that correlate to an EPZ or it just correlates to modeling protective measures irregardless of whether or not there's an EPZ?

MR. SMITH: Yeah, it correlated to modeling the protective measures. But, for the task force in NUREG-0396, they used those insights as an additional line of reasoning that ten miles was adequate. They could achieve those dose savings, as was the objective.

MEMBER ROBERTS: Right, because the bars are all pretty low at 15 miles --

(Simultaneous speaking.)

MR. SMITH: Yes.

MEMBER ROBERTS: That's, kind of, the way I read it too. So, it's really telling you that a ten-mile, you know, kind of a mental thought process is a way to think about it --

(Simultaneous speaking.)

MR. SMITH: Exactly.

MEMBER ROBERTS: But what you're telling us is, from a capabilities standpoint, you expect the community to have the capabilities regardless of what you call the EPZ.

MR. SMITH: Yeah, and there's also qualitative insights here, right? So the ten miles was also based on an understanding that you would include enough numbers of jurisdictions and, you know, response agencies within that area so they could take action within and outside that zone.

MEMBER BIER: One other question. In what fraction of cases, I mean, roughly, qualitatively, is the EPZ just kind of proactive or precautionary? Like, we're going to get you out of there just in case there's a lot of contamination. And what fraction of that is, nope, now you're never going to be able to live there again. Do you have a sense of that?

MR. SMITH: Yeah, that is a great question. And that is where you got to take a step back and look at -- in EP, we're trying to do risk management, okay? So, the accident has happened, now we're trying to manage those risks. And so, we have different strategies that we can employee, precautionary, risk-informed, or dispersive.

Precautionary strategies are used when there's a lot of uncertainty and consequences could be high. And when you go back to the insights from the Reactor Safety Study, remember the thinking was you could have a release within 30 minutes, consequences proving life threatening. So we took a precautionary approach. But, when we look at the safety of advanced reactors, small modular reactors, there's an opportunity now to take advantage of risk-informed strategies.

And so, we rely less on the emergency planning zone in terms of implementing those actions and more on the insights of what we understand what could happen and we have to consider, you know, what are the external factors. Maybe this is an event that's happening in the midst of a severe seismic event, what is the right action? It may not be the appropriate action to say, everybody evacuate, when you're putting them into more harm.

MEMBER BIER: One other comment. Even for the large light-water reactors, long term relocation is not without its own harms and burdens for the population, even if not health related. And I have a small study, I could share with people later, that argues that possibly even the EPA protective act of -- action guidelines are too restrictive and that there may be some people who would want to remain in an area even that violates those guidelines.

And, you know, it's a tradeoff. You know, you can cut radiation dose to the population lower by relocating more people, but is it really net beneficial? So I'm happy to share that or post it in the record of today's meeting or whatever, it's a published document, but.

MR. SMITH: Yeah, and this is an area where we are very active within the federal family. So there's a Federal Radiological Preparedness

Coordinating Committee and that's where we all get together to assist FEMA. We bring our risk insights so that state and locals have the tools, the information, the knowledge they need to make those risk-informed decisions within the context of implementing the protective action guides.

One example we saw during COVID is that a few states raised their tags for evacuation because they recognized that, if you evacuate and sheltered people within community shelters, the risks were higher, from COVID, than staying at home. Can we go to the next slide?

Just a final point to emphasize design information, risk insights -- which are very useful to help us inform EP, to help us understand how we can make risk-informed decisions, but, ultimately, the effectiveness of the emergency plans independent of a probability.

We have to deal with all the residual risk of the facility, and this means recognizing that there may be events, very low likelihood or consequence, that we need to act on. But a key concept here is, that doesn't mean you develop specific plans for those worse case events. We have to understand the planning concept here that even goes back to the 1970s and

NUREG-0396 which is that, sometimes you may find you're beyond your capabilities and you need to get help from state and the federal government.

And that's part of our planning concept. It's embedded in our national preparedness goal, it's what we call the whole-community approach. And so, we embrace this all-of-nation approach because it gets very efficient, effective use of our resources. So, the risk-informed performance based planning, we give adequate protection of public health and safety even for those very low likelihood events.

CHAIR MARTIN: I think this is a good break point, right? We were like an hour behind, maybe, or no? We're good?

(No audible response.)

CHAIR MARTIN: I just -- you know, looking at the agenda and we're talking about accident selection, and then --

MR. RECKLEY: I don't think it's quite that bad.

CHAIR MARTIN: Okay. Good enough. So let's break for 15 minutes, or 12 minutes? I know that is short, but let's reconvene at 10:30.

(Whereupon, the above-entitled matter went off the record at 10:18 a.m. and resumed at 10:30

a.m.)

CHAIR MARTIN: Okay, it's 10:30, we're back. And we're picking up with the slide that's entitled Guidance on selection of accident scenarios for demonstrating general site suitability under 10 CFR Part 100.

MR. RECKLEY: Okay, so this is Bill Reckley again, I'll take this part. And again, this is largely a summary of the vision for Reg Guide 4.7, some of the thinking that went behind it. And that leads to -- although we're pursuing technology-inclusive approaches, we do still have a long history of light-water reactors. So the question always comes up, why are activities going forward continuing to split. Light-water reactors, we'll do it this way. Non-light-water reactors, maybe SMRs, we'll do a different way.

We're not, in the guidance, saying that a light-water reactor cannot pursue alternate approaches. But, given the history, the infrastructure, both on the regulatory side and then, also, on the industry side in terms of codes and standards, including the PRA standard that works a little differently for light-water reactors, because it was setup for different questions, if you will, than the non-light-water reactor PRA standard.

So, for all of that -- all those reasons, we end up going forward, sometimes out of ease of use, distinguishing between an approach for light-water reactors and the approach for non-light-water reactors. And that is true in Reg Guide 4.7 and the consideration of population density.

So we'll go through, for light-water reactors, both what we talked about largely already, the determination or confirmation of the exclusionary boundary and low population zone, and then the 20-mile -- existing 20-mile distance out to which we consider population density, an alternate mechanism to do that. And then we'll just repeat for light-water reactors using the licensing modernization project methodology, or LMP methodology. And then a quick mention of non-LWRs, should they not choose to use that approach.

So, I'll just go forward --

CHAIR MARTIN: Just real quick. The premise that we've already kind of expressed earlier in the meeting for all of this is the low likelihood of failure by containment bypass. Now, you know, I'm familiar, of course, with like, the SAMDA or SAMA, you know, and those activities which can be used to show that. And it occurs in the environmental report. But

I'm not familiar where it might show up more in a Part 50 context. I mean, certainly all the pieces are there but, you know, when is that, kind of, established by the application? It is only in the EI -- ER, in the environmental report, or is it somewhere else?

MR. RECKLEY: Under the existing structure that we have, it would show up in a number of other places. It would show up in the environmental assessment and the SAMA analysis, it would also show up in Chapter 19 which is where they summarize the PRA. And that is going to, for light-water reactors, the figures to merit are large release and core damage, so you start to get into the surrogates, traditionally, for light-water reactors, versus actual dose calculations.

So that information would be there, it would be considered. They'll have to show in Chapter 19, is the severe accident design features, that comes out of the severe accident policy statement but it's also the PRA, that would say what they do if there's core damage in order to protect containment. It's a soft regulatory area but, in addition to the physical structure of a containment, a system, you're also going to have severe accident management guidelines that are the operational side of what do operators do to try to save containment, should you have a --

So, there are a number of areas where it will show up on the plant design safety side, if you will -- I don't like that term. But outside of the environmental SAMA analysis, it'll all show up in Chapter 19.

CHAIR MARTIN: Maybe you could state the obvious. As we move to plants that credit functional containment, it gets a little trickier about what all this means, right? So, hopefully you touch on that.

MR. RECKLEY: We'll touch on functional containment, because it and the licensing modernization project go hand in hand. It really is the LMP that kind of enables you to take better advantage of the -- but we'll get into that, yes, we will.

Okay, so this slide we've talked about a number of times for traditional or light-water reactor approach to confirming or determining the EAB, the exclusionary boundary and low population zone, so I'm not going to touch on it again. But, basically, it is an assumed major accident radionuclides put into containment. Containment will leak at a given amount, that amount will be defined in tech specs, it'll be tested to show that that is, under those conditions, the amount that it'll leak.

Now, with degradation and severe accident studies, containments may fail later but, under this assessment, that's the way it's done to calculate the offsite dose. Next slide.

So, now we get into the population density. This is the distance out to which the NRC would look and do a confirmation that the population density does not exceed 500 persons per square mile out to a distance. As we talked about earlier, currently, up till revision four of this reg guide, that distance was established, by a generic assessment, at 20 miles. But, based on feedback, people wanted flexibility to maybe less than 20 miles.

And so, Reg Guide 4.7 defines this methodology. It first says, you can assume the same source term into containment as Reg Guide 1183 coming out of risk-informed studies, NUREG-1465 and others. That puts the radionuclide inventory into the containment. But, as a distinction between this assessment and the previous one on exclusionary boundaries and low population zone, the applicant needs to consider the containment performance in a severe accident.

And that does not necessarily mean that they have to assume containment fails, but they have to do and show in the application how they considered severe accidents. Under the severe accident policy statement, they may have added specific design features, they may have particular procedures to address severe accident conditions that would, maybe, justify not assuming a total failure of containment but maybe a degraded containment compared to the tech spec leakage values.

CHAIR MARTIN: We have a question by our consultant, Dennis Bley. Go ahead, Dennis.

DR. BLEY: Hi, Bill. Isn't there also a requirement that the applicant has to do a population growth study for the life of the application?

MR. RECKLEY: They have to project it and, this is from my recollection, we'll consider it out, I think, five years. They -- the one thing that we want to -- do make clear is that the 500 people per square mile out to any distance that gets set, either the 20 miles or this alternative, does not become a requirement that they need to maintain, right? So, ten, 15, 20 years from now, it might be higher in certain segments. It's a siting evaluation, it does not become a long-term requirement to maintain the population density --

(Simultaneous speaking.)

MEMBER HALNON: Bill, this is Greg. I was going to butt in earlier, but I wanted to make that clear that this is a one-time analysis for siting. The evacuation time estimates, I think, requirement for six years looks at population growth and whether or not the EP, evacuation times and everything else are still appropriate.

MR. RECKLEY: And those will be updated, and Todd --

MEMBER HALNON: Right, those are continuous, these are continuous issues. This is just a one-time only.

MR. RECKLEY: That's right, this is an initial licensing decision. So, sorry, Dennis, I don't exactly remember. But I do remember we ask them to show, I think it's five years that this would be in place after the licensing decision. Something like that.

DR. BLEY: Greg's comment did some further clarification. Thanks.

MR. RECKLEY: Okay.

CHAIR MARTIN: Just a clarification. So, after those five years, population increases, that's okay. It's all underneath, kind of, the assumption with the license that's --

MR. RECKLEY: Yes. Although, history would show that, as it does that, questions arise. And then you have to deal with it either in emergency preparedness -- it may not require anything but it's going to come up in conversation, right? It has --

(Simultaneous speaking.)

CHAIR MARTIN: It's all part of the maintenance of the EP.

MEMBER HALNON: Those other processes in a community that causes zoning board meetings, other public and stuff that -- stuff comes into play in additional to the all-hazards planning that the containment does what the local --

MR. RECKLEY: And then you also have, in addition -- we're not talking about them today, in addition to the dose related criterias, like low population zone or population density considerations, you have security related ones, like owner-controlled area that's going to define some area beyond. But, Todd, did you want to --

MR. SMITH: One thing, and maybe somebody can look this up, I do think, actually, the population index was out of maybe 50 years?

MEMBER HALNON: I think it's 20.

MR. SMITH: Twenty years? Yeah, I think it's more than -- a little bit more than five. But, yeah, you're exactly right. So then we account for changes in the offsite conditions in the evacuation time estimate --

(Simultaneous speaking.)

MEMBER HALNON: That's a 10 year –

(Simultaneous speaking.)

MR. SMITH: That's a ten year and then, in between decennial censuses, every year the licensee has to look at population increases and, if they exceed certain criteria, then they update the ETE. It also accounts that every ten years not just population increases but changes in infrastructure.

MEMBER HALNON: And in my experience, it's the licensee's responsibility to intervene in other projects, such as a natural gas plant or a propane gas plant or a proposed build of a nursing home right next to their plant. The licensee has a responsibility to maintain their EP program appropriate, which would cause them to have to intervene in, potentially, a public hearing on -- double zoning hearing or something to that effect.

MR. RECKLEY: Yeah, there's two different things. One be, like, a pipeline which would be an additional external hazard.

MEMBER HALNON: It would be an external hazard, yeah.

MR. RECKLEY: And then the other one that --

(Simultaneous speaking.)

MEMBER HALNON: I tried to give both examples. We did intervene in a gas facility and we also intervened in a nursing home that wanted to build right next to us.

MR. RECKLEY: All right. So after consideration of severe accident potential impact on containment, again, it could be -- they could argue in the application that that's addressed through measures they have taken, both operational and design.

They will reach a leak rate from the containment to continue the calculation, or the assessment, and the dispersion to the atmosphere, into the local populations. And then the alternative is that the population density is less than 500 persons per square mile out to two times the distance at which the calculated dose to an individual is 1 rem over 30 days.

That was -- it may sound like an odd

number, we picked it for a number of reasons. One is, the 30 days is the typical dose calculation under licensing modernization, so we figured they were doing it anyway.

Another one would go a little bit to the societal measure. This is beyond, this is a lower number than may be necessary for prompt protective measures, but it starts to consider societal measures such as relocation.

Not one-for-one, but in our thinking it contributed. And as you look at the commission paper we laid out that this number would contribute to limiting the societal impact of relocations by having the number of one rem over 30 days.

Next slide. So now we get into the non-light water reactors and the concepts of functional containment. And this is where we need to start the sensitive to the terminology and the way we described things changed.

On the top of this figure you'll see Reg Guide 1.183 for light water reactors. There's assumed to be core melt, losses of other, protections. Such that you have a major accident and you put the radionuclide mix into the containment. That's typically called source term. Source term into containment. And then it's modeled, as it's shown here, through the leak rate from containment and the dispersion offsite.

When you go to a functional containment concept you may have much less reliance on a last physical structure. More reliance, for example, on the codings within the individual TRISO particles for, and surrounding graphite and the matrix.

So we change the way we address through a functional containment to say, ultimately it is the whole series of barriers that we're going to be assessing. And the term functional containment starts in the core, inside the kernel. And you take credit for every barrier to its release.

And we call the source term what escapes from the plant. And that may be, likely that's going to be from a structure, like a reactor building. But the reactor building may not be credited within the assessment as a, nearly to the degree that can essentially need tight containment.

So even when we are talking like the source term it changes from the point of reference being into the containment. And for functional containment and LMP it changes to be a release from the whole plant.

MEMBER HALNON: So can you comment on liquid fuels?

(Simultaneously speaking.)

MEMBER HALNON: Would that final barrier just be re-labeled all the containment things going on at the same time?

MR. RECKLEY: That would depend on how that applicant wants to pursue their license. If they want to approach it as a functional containment and take full advantage of radionuclides being retained in the salts, and the salt solidifying should you have a break, and therefore we don't really need to put much emphasis on the structure, they could pursue that approach.

If they wanted to say, we are going to be an essentially a leak rate (phonetic) containment, they could take a more traditional approach, and we'll talk about that going forward, they'll be challenged because we don't have a Reg Guide 1.183 source term from the salt reactor into a structure, they would have to develop that.

But it's really up to the application to a flexible approach. If they take a functional containment, I think they would more likely do that because they would be able then to take more credit for the retention of the radionuclides in things like the salts themselves.

MEMBER HALNON: So the first one in will be an important --

MR. RECKLEY: Yes.

MEMBER HALNON: -- presence.

MR. RECKLEY: So if you go to the next slide, Anders. This is just trying to slide --

MEMBER ROBERTS: Can you explain that previous slide what a Reg Guide 1.183 release is?

Is there an intent to revise the reg guide to cover all these different non-light water reactors?

MR. RECKLEY: No. Not at the current time.

MEMBER ROBERTS: So what does that mean? I thought the way this work is that there is an assessment based on the PRA and the licensing basis events and those would be risk sorted and there would be some assessment and cliff-edge or defense-in-depth to make sure it's a complete list, but is that what you mean by Reg Guide 1.183 source term?

MR. RECKLEY: The Reg Guide 1.183 source term is what we've talked about a number of times. The major accident, a release from the fuel into the containment.

The Reg Guide 1.233, which is the licensing modernization, doesn't have the equivalent of a source term, it includes the concept of a functional containment and basically says, every event that gets analyzed will be analyzed to see if it falls into a category that has a release. Many will stop at the, you know, the first barriers, the fuel doesn't overheat. No release from the fuel into the coolant or from the plant.

Some, the design basis events, beyond design basis events, may include releases from a system offsite. And there's would be evaluated by each applicant, for each technology, for each event to determine what the release is. We would not have an equivalent of Reg Guide 1.183 that says, here's how you do that.

MEMBER KIRCHNER: One problem that I see, Bill, is that for the general public looking at this, we have non-LWR designs using really conventional metal clad fuel making a functional containment argument, which is a lot different than the example you gave of the TRISO.

How is the public going to be convinced that they are provided equivalent level of protection, starting with the siting, when probably their analysis will always show a source term much less than the predicated worst case source term that goes into 1.183 for a large LWR?

MR. RECKLEY: I don't, I won't say it won't be a challenge, but I think the argument in us trying to explain it will be something like, here's how this is done for the existing fleet. We took information from Three Mile Island, how much radionuclides actually made it into the containment?

We dove on that knowledge, we updated our guidance. And that was a real event, real assessments. And this is the result in dose.

Now as you go to, let's say molten metal, liquid metal reactors, and you go to the public and say, here's we're using a functional containment analysis and we still have a structure, but our analysis shows this is the hold up within the sodium. It's within the liquid metal itself.

MEMBER KIRCHNER: Or the salt.

MR. RECKLEY: Less, less goes into the containment than does for a light water reactor. But we model what goes into the containment and then the release. But it's less than a light water reactor because it's retained by another system that's included within the functional containment.

I'm not saying it won't be a challenge to try to explain that, but that will be what we have to explain.

MEMBER PETTI: I think that personally I think the challenge comes down to the database to prove it where, you know, a lot of LWR have spent lots of money on that. There's lots of data on the TRISO and the data reprogramming.

But it will useful to see in metal fuel, there have not been tests specifically focused on what the source term is. Can you put together what they have, and I've seen some of the reports, is that sufficient enough to make a licensing case. And that's --

MR. RECKLEY: And we're not going to weigh in here --

MEMBER PETTI: Right. Right. Right. Not here.

MR. RECKLEY: Right.

MEMBER PETTI: But that's where it's going to be I think.

CHAIR MARTIN: But, you know, as we have talked to some of the design standards, you know, I can't help but think that there should be a functional containment topical report, but really it should be all encompassed into a mechanistic source term. And of course I've seen, those have been submitted, but doesn't it point to kind of new requirements, you know, that go all the way back to the inventory. And all the barriers in-between. Those things should be pretty hefty documents.

MR. RECKLEY: And address the uncertainties and the available data. But yes, what you, what the agency will see will be a mechanistic source term doc not a functional. It's the same thing, but it's a functional containment talk.

CHAIR MARTIN: Right. Right. Which it equates to.

MR. RECKLEY: Right. Okay, Anders. So this slide is basically showing the same thing. Going back to the bowtie, and just trying to deliver a message that, again, we're changing the reference point for the top level event, if you're describing it using a bow tie, from core damage to release.

And it may not affect the design, but it might affect how things are discussed. And if you use the same high plant level assessment, then prevention would go to what prevents the release.

And that would include functional containment on the prevention side of the ledger, and siting emergency preparedness. Other things might, would still exist on the mitigation measure, but it might just change the way the conversation is held.

The other focus on mechanistic source term, and technology inclusive approaches, is we start to talk about safety functions versus specific cladding, pressure boundary containment. They don't, all the technologies don't have those same things and so you start to talk about safety functions or reactivity control for cooling and for containing the radionuclides. So just as we move forward, it's the same concepts it just, it changes the conversation somewhat.

Next slide, Anders. So that then goes to what would be the approach under Reg Guide 4.7 for addressing the exclusionary boundary and low population zones for a non-light water reactor using licensing modernization, or LMP. And what it says in Revision 4 to Reg Guide 4.7 is, that assessment uses the design basis accidents.

Which again, go back to the previous discussion we had with the light water reactors. It is a test of your safety related equipment to control a release to the reference values at the exclusionary boundary for low populations.

And so this is just reflecting what's in the reg guide. That it's the design basis accidents under LMP that you assess to show you're less than the 25 rem over two hours at the EAB or over the month or the duration of the release for the low populations.

MEMBER KIRCHNER: That's the inconsistency I was trying to highlight though, Bill, in my estimation that for LWRs you don't limit yourself to a design basis event, you assume you have a major loss of, a major core melt. One would hope that all the DBEs for any design would calculate through Chapter 15 and see no major release.

MR. RECKLEY: Right.

MEMBER KIRCHNER: So that's a perception problem.

MR. RECKLEY: It is a delta. The logic is that what you do under Reg Guide 1.183 and that approach is to test your last safety related barrier.

MEMBER KIRCHNER: Right.

MR. RECKLEY: That does assume, the way it's laid out, you had failures of other safety related equipment in order to get there.

MEMBER KIRCHNER: Right.

MR. RECKLEY: But it is in the end a test of your last safety related barrier. And that is a difference from LMP because you're able then to look at the performance of all your safety related SSCs going into the assessment of the design basis accident to show that the release is less than the reference values.

It is a difference, and we get into this constantly on LMP, that in one area there is a perception, and it may be true, that you're somewhat less conservative. But the reason for that, at the DBA stage, is because you have a much more structured assessment of the beyond design basis events than what you do for the light water.

That the argument of the DBA, for existing light water reactors, and it's moderated over the years, as we've taught, because you had to do responses to severe accidents and come up with SAMGs and do various things to address issues as they've arisen, but the concept still is there that the DBA is a very conservative event meant to bound other more significant events. That you don't, or at least in the early part of the industry, you didn't assess.

And LMP, again, the argument is it's more systematic approach over the whole range of accident frequencies and therefore you might be more conservative here, but you're less conservative at the

DBA, but more conservative in the BDBE, beyond design basis event category, and you end up in a similar place.

MEMBER HALNON: So, Bill --

MR. RECKLEY: It's just a redistribution of assessments.

MEMBER HALNON: -- one of the issues that we have for public perception, and the ability to drawback on the conservative nature of today's analysis that we use for large light water is sort of the letter that you used, and I'm not saying it's wrong I'm just telling you this is how it works. And it worked the same way during our simulator evaluations when we had tests.

You mentioned you had to have a lot of safety related equipment fail to get there. And that's not, that language makes you believe that safety related equipment is going to fail within just your single failure that you assume.

It's in likeness to the simulators where an instructor wants to get to core melt so you have to get to a general emergency so they started creating all these crazy scenarios to get, finally gets them there. Five things are tagged out on separate trains, your already diesels, two diesels are pulled apart.

Something that will never happen based on the administrative controls, tech specs and other things.

So it's sort of negative training. You start believing that that happened to get you there. It would be much better if you just said, we're going to put half the cooler in the sump and measure that source term and let it get out of the containment then say that I'm going to have to have three trains of this panel, one train of that panel.

And that has caused, at least in my mind, and I know others, that these unreal sequences can occur. And I think we said earlier on that these access sequences meant to, they're all hypothetical and we create them.

So I would just caution us to say, you know, you have to have a lot of safety related for them to fail because that provides a negative connotation on the safety related equipment and our ability to be on the left side of this scope. That was just a comment.

MR. RECKLEY: And so, Slide 29, what we're trying to show is under this assessment for non-light water reactors how do you reach the alternative to the 20 miles per 500 persons per square mile population. And so, Reg Guide 4.7, the revision that's been issued, calls out that those you look at under LMP, the design basis events and beyond design basis events, so that's taking you in frequency range from 10 to the minus 2 down to 5 times 10 to the minus 7 in the categories with, again, the emphasis that 5 times 10 to the minus 7 is not a hard number.

So that is what we ran through in the commission paper, and in ultimately, it is incorporated into Reg Guide 4.7.

MEMBER ROBERTS: And one difference between Reg Guide 4.7 and the EPZ Reg Guide 1.242 is the statement in the reg guide about treating of uncertainties. The EPZ reg guide says you need to consider probabilities of events, you know, after consideration of defense-in-depth considerations and cliff-edge effects.

There is no similar wording in this reg guide so I was wondering why. One theory would be that beyond PRA requires it. And so, if beyond PRA requires you to look for cliff-edge effects and defense-in-depth assessments and maybe screen in scenarios but otherwise be screened out of frequency. And it's already done as an end poach, then as the question why is it, and why not the other. I've already gave a comment on what the intent was.

MR. RECKLEY: I don't know that we had an intent. I think it is, as you described it, that the Reg Guide 4.7 was reflecting the use of LMP, which includes those directions. So I believe, I don't recall any conscious thought to leave those out from here. It was just that they were already included. The considerations of uncertainties and the consideration of (audio interference).

MEMBER ROBERTS: Okay, thanks. And your last few slides talk about defense-in-depth and cliff-edge effects?

MR. RECKLEY: Right.

MEMBER ROBERTS: I'll reserve my questions for then.

MR. RECKLEY: Okay. So then, Anders, go to the next slide. So then the last thing addressed in the regulatory guide 4.7 is for non-light water reactors that may not use LMP or that kind of approach, maybe use a more traditional approach.

This goes to the discussion we had earlier. They are allowed, or not allowed. The guidance includes higher level instructions on how that might be done. Largely it goes that they could go back to a more light-water reactor type approach, include a source term (audio interference) containment structure, and then model it.

As I mentioned earlier, the guidance says that they could follow that approach. The challenge in that approach is that we don't have the equipment in NUREG-1465 or the TID or, for those other technologies but they could pursue it.

Anders. That really is the summary of how the events are looked at in terms of the Part 100 siting. There's no additional questions on that?

Again, you can look at Reg Guide 4.7 Revision 4 and the SECY paper. What year did we do that? Anyway. The reference SECY paper. 1845 I think.

MEMBER KIRCHNER: Is it your sense, I know it's going to be application specific site, site specific, but given the fact that people are talking about re-purposing coal plants and they're existing infrastructure, I'm not thinking right now of Wyoming, but I'm thinking of other areas maybe more on the eastern side of the country. Is it the population density calculations or estimate that's going to dominate, you think?

MR. RECKLEY: It can contribute. And if you go back to the original paper, we looked at population density from two perspectives.

If you're using a micro-reactor to do an industrial site, let's say a mining operation or a small village, oddly enough the 500 people per square mile might be the village.

MEMBER KIRCHNER: Right.

MR. RECKLEY: So you would have to put the reactor outside the village. So we were looking at it from that perspective. That's one way you can exceed 500 people per square mile. Is it a small spot? Small but concentrated spot?

And then the other way would be, in the more typical way, in the lower 48 if you will, which is the use of them in something like to replace the fossil station. Well a lot of older fossil stations are going to be closer to population centers than are large light-water reactors.

And so, if you can change that from 20 miles to some lower number you may be able to use that fossil station, propose to use it, whereas, and again, I go back to the Oak Ridge assessments that they did back when we did the paper, and continue to do, to show that taking the 20 miles out and using a different number does allow at least other sites to be considered that would be excluded.

So more questions? We can jump into

defense-in-depth. This is another interesting and kind of philosophical and long history kind of topic.

I put up two references that are useful, I believe. The first is NUREG/KM-0009 which is kind of a knowledge management collection of the NRC and AUCs approach to considering defense-in-depth.

The other one listed here is the International Atomic Energy Agency, IAEA, has incorporated defense-in-depth concepts into a lot of their design guidance and operational guides.

And the base documents, on which a lot of that is based, is INSAG-10 and INSAG-12. So, just again, useful references as we get into this a little bit. We'll start to talk about what was brought up earlier, the five levels of defense-in-depth in the IAEA documents.

So next slide please. So I know this is too much to read on the slide, but it is just meant, actually, to reinforce that it's not an easy assessment to consider in that the guidance in both areas, the LMP guidance documented in NEI 18-04, and the IAEA guidance, starts to bring in the fact that you need to consider kind of a holistic view, plant design, plant operation, plant programs when you're doing this assessments.

So NEI 18-04 does that specifically by having plant capability defense-in-depth. This is like redundancy, diversity and actual systems performing safety functions.

And then also programmatic defense-in-depth. I have a system, I like to bring up that as we're looking at this it might be a matter of do I need a guard pipe around my primary pipe. And the decisions that people are going to make is, I can put in a guard pipe or I can survey my single pipe without the guard pipe more often perhaps. And that's, you know, that's something for them to consider, along with the uncertainty. Or I might do both, depending on the uncertainty.

So those kind of things you have to look at in total. How much safety margin do I build in? Well again, how much uncertainty am I trying to address by building in safety margin.

And then under LMP those things are traded back and forth using the PRA and other parts of the methodology, which also includes, and we'll talk about it later, the integrated decision-making process or an expert panel, engineering judgment, however you want to characterize it to basically in the end say, yes, this is reasonable, and then we can proceed.

CHAIR MARTIN: Let me break in real quick, we have a question from Dennis.

MR. RECKLEY: Yes, Dennis. You're muted, I assume. We're not hearing you.

DR. BLEY: Sorry. I clicked on it, it just didn't clear.

Yes, Bill, the NEI 18-04 sketch that's up here I always did like, but had some questions came up recently as we were talking, and a couple of issues arise for me. And I wonder if you had thought about them and how you think the staff will deal with these when they start reviewing defense-in-depth arguments and submissions.

This process, on one hand, is very complete and looks at almost everything I can think of. And urges you to be expansive in applying it. On the other hand there is a sentence early on, in the text I think, that says, eh, this is an iterative process, and then it doesn't talk more about that.

Some years ago I was familiar with a book on ship design that talked about a design spiral, but you keep revisiting the issues of design as you go around the spiral in that iterative way.

When one reads the text supporting this diagram, it's possible to read it as saying all of these things apply after you've selected the LBEs. And I hope that's not the intent.

I hope the intent is that we keep revisiting this all along the design process until we get to a final stage because that issue we talked about earlier of, you know, starting with a clean sheet of paper and thinking of all the things that might be there that we haven't thought of ought to arise again and again as your knowledge about aspects of the design, the chemistry, the physicals evolve. Can you speak to that at all?

MR. RECKLEY: Yes. And I think it's true that it's considered to be iterative all the way through the processes. Now the odd part is, me, as the regulator, get involved in a certain place. Right?

And so for a combined license application that should be near the end of all the iterations. Okay? That's not to say there won't be lessons learned and changes that have traditionally been, but it should be more or less the designer has gone through all those iterations.

What we're actually seeing now, given that the two leaders under the advance reactor demonstration program are going construction permit operating license, is we're seeing a little more of that iteration because of the construction permit stage. It can be a little less defined, a little less justified.

For example, even, gosh, there is a focus initially on the internal hazards. And some of the uncertainties and additional analyses for external hazards will come later at the OL stage. And introduces some risk for the applicant, but that's the way the iteration is working between the CP and the OL.

But the short answer is, Dennis, it should, from the designer standpoint, be iterative all the way up until they reach their conclusions that they're putting in the applications. From the regulators point of view we'll see that in different places depending on what the application is.

DR. BLEY: Okay.

MR. RECKLEY: And we're seeing that in real time right now.

DR. BLEY: You can audit some of the supporting materials that were developed along the way should we come convinced that this has been un- thoroughly.

MR. RECKLEY: Right. And then from a real practical matter, right, they don't want to be iterating on things that are, I'll use an old term, almost nonreversible, right?

You don't want to do something that has you have to tear up the base matt if you were raw, right?

(Laughter.)

MR. RECKLEY: So you want to do iterations also dependent on the application you're making and the flexibility you're going to have to adjust to whatever the iteration might show. So you might feel a little more comfortable if it's putting in a bigger pump, but it's not going to be something you want to pursue if it's redoing civil structural --

DR. BLEY: Okay. And I guess the issue comes up when you read some of the language it says here, we truncate all scenarios below a certain threshold. But before one gets to that point I would have hoped you were being very thorough in your searches so that you have some comfort that you've already looked at very unlikely but could be very bad if they occur.

MR. RECKLEY: Right. And we'll address that a little bit as we get into the topic of cliff-edge. But also, and Anders, please weigh in. Under the PRA standard you need to have a rationale for where you're making those decisions that I don't need to consider that further. Anders?

MR. GILBERTSON: Yes, this is Anders Gilbertson and staff. Yes. And that, you know, that rationale, and when you're looking at the requirements in the non-LWR PRA standard and how you apply those judgements, you know, there are a set of what essentially are the most qualitative screening criteria that can be used as a matter of analyzing your PRA. So not, it's a matter of constructing your PRA if you will.

They're qualitative and there is some sort of more semi-quantitative, qualitative and then quantitative screening criteria that you can apply.

So if you imagine the range of potential hazards that you can look at, you know, clearly some of those are going to be, have a more qualitative justification. Something that's more akin to a plausibility argument, if you will. There's different words that you could use to characterize that, but that's generally how I kind of think of it. But yes, that's, it will be a range of justifications.

DR. BLEY: Okay, thanks. And I guess one of the recent applications we look at, the applicant at least convinced me that they were very, very thorough in looking for things that might take away from the assumptions of their design. And one includes things that would show up here in your defense-in-depth analysis.

MR. RECKLEY: All right. So I think that that basically gets the message on this slide. You're looking, the whole intent of defense-in-depth is you're looking holistically. And it's including, under both approaches, things like surveillances, the role of operators, redundancy and diversity in the planned systems, and so forth.

Next slide.

MEMBER ROBERTS: So, just an extension of Dennis' question. Is there a frequency cut-off at which you stop looking for defense-in-depth or cliff-edge effects or is it all qualitative and more of a deterministic thought process of when do we stop?

MR. RECKLEY: I would answer that, that again, once --

DR. BLEY: This is Dennis Bley. If there is still talking going on I've lost it out here.

MR. RECKLEY: Dennis, we can hear you.

MR. GILBERTSON: Yes.

MR. RECKLEY: Okay. All right, so the

staff can try to contact Dennis I guess. Okay.

So, the answer to that, I think is that defense-in-depth decisions ultimately need to factor in all of those things. And as opposed to saying there's a cutoff, at which I don't need to consider defense-in-depth, the way it typically works is at that area, this 10 to the minus 7 kind of range, that you're really calling on the integrating decision-making process where the expert's panel to make the determinations, right? But the higher numbers, 10 to the minus 5, 10 to the minus 6, the PRA is telling you kind of what you needed in order to get that number.

But as you get near that 5 times 10 to the minus 7 under LMP, the reason we emphasize time and time again it's not a hard line, is because that's where the engineering judgment really needs to come into play. Is there events that are right below that, what are the uncertainties, is there a cliff-edge such that one of those events is lying beneath that value, isn't like normal distribution but it's a sudden change. And we'll get into that with the definition of cliff-edge.

So the short answer is, there is not a firm cutoff, but as you're looking in that range, 10 to the minus 7 area, it's historically been identified as diminishing returns if you will. And so I don't need to take major measures to address the events that come below. Anders, go ahead.

MR. GILBERTSON: Yes, this is Anders Gilbertson with the staff. I was just going to add that in terms of when you're developing the PRA if the features that you have in the non-LWR PRA standard would, generally are going to go much below the sort of threshold or cutoff that Bill is kind of alluding to here as a matter of defense, decisions about defense-in-depth.

You have requirements that say you need to look at the conversion of your PRA results as you go down in lower and lower request numbers. If I go down a decade in truncation of my cut sets and my event sequences, do I all a sudden get a spike in my risk. Okay. So it's not converging to something.

So, and then of course when you're looking at it through LMP, when you're looking at event sequences below that 5 to the minus 7, the notion is still that you're retaining those in the PRA model. So they're not disappearing, they're not going away, they're still there for exactly that purpose of looking at those cliff-edge effects.

MEMBER ROBERTS: Right. The LMP document

does not imply a lower threshold for cliff-edge as depths assessments. But we got our topical report with a proposed in the lower cu-toff and I was wondering whether that's appropriate or whether that's something that, you know, while you institute that you might be cutting off something that would otherwise be picked up.

MR. RECKLEY: And then this was raised earlier. The other thing to keep in mind is, as you're looking at the plant design you might actually even use different levels than if you're looking at operational society, even including emergency preparedness because you might reach a point to say, the external hazard, I don't need to, hypothetically I don't need to consider a hazard above this because in emergency planning space it's already a bad day, I'm not going to get that much extra from adding distance to the emergency planning.

That's not to say that same cutoff would, by definition, by the same cutoff that you're using in plant design. That might go to a higher acceleration saying in the plant design I have to, either in probability or in actual physical gram acceleration use a bigger number.

You're looking at the barriers, again,

kind of holistically, but you're also looking -- and the staff that are looking at each barrier is looking at if from their own point of view -- at what's the point of the barrier? And there might be differences in how it's looked at. That might add complexity to the situation, but it's the reality, I think.

MEMBER HALNON: Bill, one other question. We're getting applications in with a statement that there I no operator action required for responding to licensing basis events. And they kind of waived that flag saying, see how unimportant the operator is. But they're clearly included in the defense-in-depth.

So can you comment on how that is viewed relative to responding to the license basis events and no operator action required?

And I'm assuming they're just thinking the transient piece of it, but just --

MR. RECKLEY: Well, yes, I'm not involved in the actual reviews of what we're, I haven't right now. But I've been in the hypothetical discussions for a long time. And it does range from a fairly recognizable approach that we have now, licensed operators doing actions in response to transients, to operators not required to do anything but they may be there for defense-in-depth. And you start to hear arguments that do the, we don't need operators even for defense-in-depth.

So that will be up to the applicants to try to justify the, and I'll agree, I think maybe it was behind your question. The great thing about operators is they offer flexibility. Right? A SSC is going to do what the SSC is going to do. A person can do what a person can do, and they also can think what, that I might need to run out and get the battery out of my car, right? There is not an SSC that's going to do that.

MEMBER HALNON: Well, and the question really comes down tom, can I credit, can I make that statement that there is no operations required, operator actions required, and then still take credit for operator actions in the required defense-in-depths portion of my discussion?

I mean do those two, can you make those statements at the same time?

MR. RECKLEY: And again, we're getting ahead because this is, you know, what we'll get into perhaps down the road with antonymous operations and things that we're not willing to --

MEMBER HALNON: Willing to go to that now, yes.

MR. RECKLEY: -- to predict how that goes. But from my point of view, once you've built in an assumption that the operator is there for defense-in-depth, you are at least assuming that the person is there. And it's reasonable to assume that the person will do the action. Whether they're licensed or not. That they have a ability to do the thing. And so you would be held, is my own projection of how that would --

MEMBER HALNON: I guess that's going to be an ongoing discussion --

MR. RECKLEY: Yes.

MEMBER HALNON: -- and to what extent can you say no actions are required by the operator. But in Level 2 of defense-in-depth there are certainly, in the EP portion they've got to be there because there --

MR. RECKLEY: Right.

MEMBER HALNON: -- it's got to make a decision. Okay, Bill, we can move on. Thank you.

MR. RECKLEY: Okay. So this goes back to the same discussion we were having that defense-in-depth, depends on your context, historically reviews this language where prevention was what prevented core damage. IAEA INSAG-12 kind of includes that kind of discussion they talk about. Although they use the levels, they talk about these levels being preventive and these levels being mitigated.

Reg Guide 1.174, in terms of the guidance used to assess changes, this is for operating plants, changes the licensing basis information, also uses this same general terminology. It's not critical to the discussions but it's just, in the back of your mind if someone is saying, you know, it's a prevention or mitigated function, this is the context.

The other context that it comes up is in particular areas. Because regulations related to fire protection, regulations related to security have specific requirements for defense-in-depth for those particular areas. You know, whether it be detection and delay or detection and extinguishing the fire, for example.

So, whenever you're talking about defense-in-depth you just have to understand the context that the conversation is going. You can imagine after however long we've been at this, 80 years, there is a lot of different context in how it can come up.

Anders, go to the next slide. This is basically the IAEA approach. This figure is out of one of the reports that's there on the slide.

But this does, this is the generally approach in NEI 18-04 licensing modernization. And it does change the discussion a little bit from that previous context. Which is, there's not as much discussion of a top level event. And defense-in-depth is basically assessed by the fact that things you do for design in normal operations are meant to prevent an AOO. Anticipated Operational Occurrence.

If you have an issue and that didn't work, the mitigation of the anticipated operational occurrence is meant to prevent the design basis. And the design basis event is supposed to prevent the beyond design event.

And as was said earlier, if you have significant issues and a failure of all those systems such that you projected you would have a significant offsite release you can go to Level 5, which brings in the emergency preparedness actions, the ability to tell public, hey, shelter, evacuate, whatever, is the protective action under Level 5.

And so you start to get a different assessment. And if you look at NEI 18-04, Chapter 5, that goes through defense-in-depth, it has this kind of a logic and this kind of a discussion. And then brings in other assessments, like part of the logic is also looking at the cumulative risk measure under LMP. This is the NRC safety goals.

And the fact that you should not be relying on a single feature for all your levels, right? So if the, if you're taking credit for a feature under anticipated operational occurrence, even if it's very, very, reliable, you shouldn't be carrying that one feature to protect you against design basis event, beyond design events as well. You have to have some kind of diversity across the five levels.

CHAIR MARTIN: Is it spelled out in NEI 18-04?

MR. RECKLEY: Yes. These bullets are basically taken right out of the guidance.

CHAIR MARTIN: I got.

MR. RECKLEY: We might have had one application where they might have, probably the last of it. But we'll look at that.

Well even historically, when you look at defense-in-depth and you look at passive systems there's been questions about how much you can rely on them. So this is the guidance, there will always be challenges and twists and turns to how it's implemented.

Another question that has come up, and it's been in the background, I don't think we've put black and white to paper to actually definitively answer is the concept of an inherent characteristic, right?

So we played initially with trying even to define that. There is some definitions floating around. But it might be feasible to say, if it's an inherent characteristic, meaning this is the physics, there is no one, I'm going to exaggerate, there is no uncertainty here, then maybe you don't need additional measures beyond that. But that will, that will play out when we see technology is probably than the ones we're looking at in the current day.

So next slide, Anders. The next couple slides are just basically some background on cliff-edge, as has been mentioned a couple times. NEI 18-04 caused this out.

Now if you look at the literature there was very little discussion of cliff-edge effects before Fukushima. And then for obvious reasons after Fukushima. And water topping the tsunami wall there was a lot of discussion of cliff-edge effects.

So IAEA, after Fukushima added to the safety standard 2/1, the design of nuclear power plants, this definition, which is a fairly standard definition of cliff-edge effect, is basically it's a major change to plant conditions as a result of relatively small change in the parameter, like a flood level. And then that's reinforced in the IAEA guidance related to external hazards.

We start to bring in, and we'll get into the discussion, the cliff-edge effect beyond looking at probabilities and so forth, is the concept of available physical margin. So how much margin do I have before that flood actually causes that dramatic change, for example.

Next slide. So these are all very similar definitions, as has been mentioned. One action that the NRC did take after Fukushima was the mitigation of beyond design basis events. 50.155 of the flexible mitigation strategies just basically says you'll have to address a particular cliff-edge effect. And that is a beyond design basis external hazard, flood or seismic.

And ensuring that should that event cause a loss of electrical power and loss of availability of a heat sync, that you'll have some flexible capabilities to address that for a given period of time. So this is, in a way, a regulatory approach to a particular cliff-edge effect.

Next slide. Then within the licensing modernization, as has been pointed out, both NEI 18-04 and the non-PRA, non-light water reactor PRA standard talk, and they're not in great detail but basically bring up the topic that you need to look at potential cliff-edge effects below the threshold. So again, reinforcing 5 times 10 to the minus 7 per plant year is not a hard and fast cutoff, look below that number.

As Anders said, not only for the conduct of the PRA but to see if there are event sequences that might identify as a cliff-edge effect. Then the other place it shows it, and this goes to what I was mentioning earlier, the place you really get into these discussions is the expert panels, the integrated decision-making process. What should we do about it. And that's going to get into the discussion of how much available physical margin do we have, what is the actual frequency, and so forth.

CHAIR MARTIN: Me, I'm cutting in here.

MR. RECKLEY: Okay.

CHAIR MARTIN: At the time I read the statement about, to confirm, there are no cliff-edge effects. I'm bothered by that statement because it's not a proactive statement about searching, it's more of an induct, it sounds like more of an inductive approach. I am proving something doesn't exist.

I mean, it kind of leads to kind of another question. We don't have the guidance on how to search. Now granted, when you're talking about internal events, external events, you know, security events, I mean, the diversity of possibilities is extensive. But, you know, taking a step back it should be a proactive activity. It should be an afterthought where you are proving a negative because it's just too easy to kind of go, well I looked at that, looked at that, like they checked box, gone. And I've written something up, and you know.

It's residual risk is that last layer. It should get as much attention as any other layers as far as, you know, the development of the safe case and the review of the safe case. But, like I said, I'm reacting to the negative the way it's written there. But it appears there and maybe a couple other places.

MR. RECKLEY: Right. And I can, I was there when we were writing this stuff, but we were, I wouldn't over read it. I think what we were trying to do was to develop the guidance to say when you needed to take an action and therefore it might be worded the way you're saying, which may not be optimum.

But I've looked at it. The hazard, from our point of view, we don't need to take an action so that's why it is worded that way. It takes something like a volcanic hazard that you might look at and basically say, yes, that's in our list of external hazards we have to consider. But where my plant is located I don't have to, I know there is not a cliff-edge effect for a volcanic hazard for this location.

It might be different, I think an area that you guys are likely to see, to be honest, is in seismic, seismic historically is not really a cliff-edge, but if you introduce something like a seismic isolator that protects you up to a certain point, and then a seismic event that exceeds that might actually shake the plant more than the isolators can address, than that might be a cliff-edge. Whereas normally the seismic, and I'm not an expert so I'm going way off, but it's not been traditionally considered a cliff-edge, right?

CHAIR MARTIN: Obviously seismic has gotten a line sheer of intention on --

(Simultaneously speaking.)

MR. RECKLEY: It is a major area that we look at. I'm just --

CHAIR MARTIN: Yes.

MR. RECKLEY: -- in this particular context it gets looked at a lot, but I don't think it has historically been characterized as cliff-edge because the fragility of equipment has been modeled the way it, however it's been modeled. But the introduction of a new design feature could change that discussion is all I'm trying to say.

MEMBER BIER: I wanted to make a couple of points here. One is that I think to an certain extent I worry that that 5 times 10 to the minus 7, cutoff or guidance, or whatever, encourages kind of a checkbox mentality for cliff-edge effect. You get a list of things that are at that level, you check them all and say, none of them have a problem so I'm done.

And I really like your comment about, yes, it really depend on physical margin and, you know, maybe none of those 5 times 10 to the minus 7 events have that problem but a much less likely event does. And your example of the seismic isolators actually gets to something that Vesna Dimitrijevic and I had been contemplating earlier of, you can get a plant where sort of the base level PRA results have such low frequency of release that you look at it and say, okay, maybe we can exempt this plant from certain requirements regarding, whatever. Emergency planning or staffing levels or something or other.

But if there is one component whose failure could take you out of that regime, and the seismic isolator is a great example of that, then maybe you don't want to be granting those kind of waivers because you could end up in a situation where that would have been inappropriate. So I think that's a great clarifying example for us to have in mind as we go forward.

MR. RECKLEY: And I'm not presupposing what their right answer is.

MEMBER BIER: Yes. Yes.

MR. RECKLEY: We're just trying to say, you got to ask the question, you got to address the issue.

MEMBER BIER: Yes.

MR. RECKLEY: It may be that there is a cliff-edge, but you say it's so highly unlikely --

MEMBER BIER: Sure.

MR. RECKLEY: -- that you're not going to take it.

MEMBER BIER: Yes. Yes.

MR. RECKLEY: Or you're not. But the guidance is just trying to make sure that it gets assessed. It's not, again, predisposing what the right answer is in any particular case. David?

MEMBER PETTI: You know, just from the designers perspective, the thing about LMP that's so powerful is the balance. The list of balance across the spectrum of events so that you don't over protect something that's very low frequency and under protect something that's higher frequency. Particularly when you don't know what your events are in a molten salt reactor because according to technology, it gives you a way to think about how to logically order things that can put together a story.

But in the end, I also think margin is going to be critical when you get into these low probability events because no one is going to believe the numbers down to 10 to the minus 8. I mean, we actually are going to, by an applicant, 10 to the minus 12 --

MEMBER BIER: Yes.

MEMBER PETTI: -- for an event that has been, let's just say considered historically as a key event for that technology.

I mean, if they come in with a 10 to the minus 12 number, I mean, that's going to get some scrutiny, I would think by the staff, because it used to be an event that you had to design and deal with, so.

MEMBER KIRCHNER: And that was an internal, that would be an internal event --

MEMBER PETTI: That was an internal event.

MEMBER KIRCHNER: -- effect.

MEMBER PETTI: Yes, an internal, not external. External I think it gets, it just gets much more difficult, you know, because if you keep adding requirements on the external events it's, they are huge cost drivers to the plant. I mean, seismic isolators are supposed to reduce cost because hardening everything is so expensive. Because it's done, it's usually done late in the design process and so the iterative loop is huge and it just feeds back.

So it will be interesting to see how that, how that goes. Because, well, we've got, what, Kairos has come into the seismic isolator. But again, they're coming in under a test reactor. So a lot of this stuff doesn't (audio interference).

They're probably the first ones that actually implement, again, the small reactor, not (audio interference) bigger.

MR. RECKLEY: Okay. The last slide is just -- we are building in kind of as we go and as we update the concept of considering cliff-edge effects.

So I mention here one of our internal procedures for integrated risk decision-making that it includes. But there's not a lot.

So it's showing up currently mentioning in the three to four places that I mentioned. But, you know, as we update guidance you will probably see some mention of it getting built in to other regulatory guides and other guidance documents you might see. That was the last slide.

CHAIR MARTIN: Okay, any last questions by the members or consultants? Going around the room. I don't see anything. Looking online. I see a hand up.

So at this point I wanted to give an opportunity for public comment. It looks like we have a hand up right away. Okay. Oh, we have a couple. So we'll start off with Monica Ray. Please go ahead.

MS. RAY: Good morning. Monica Ray, energy compliance consultant.

My question kind of goes back to a discussion throughout this meeting related to the SOARCA. Now that report, NUREG-CR-70110 was issued in 2012. What are the NRC's plans for incorporating the findings of that report related to the new release time frames and new consequence levels that that report identified, and is there a schedule for incorporation of that information to existing guidance and what coordination is there with that between the NRC and FEMA?

CHAIR MARTIN: So this is a comment period, we don't necessary entertain questions. But you have, yes, your comment, your question has been recorded so we have captured that.

Next we have Ed Lyman.

MR. LYMAN: Yes, hi. It's Edwin Lyman from Union of Concerned Scientists. Can you hear me?

CHAIR MARTIN: Yes, we can.

MR. LYMAN: Yes. I just wanted to point out, Member Petti raised earlier the issue of applying the LMP to an operating light water reactor. And my impression is that the staff, the Office of Research has actually done that.

And I haven't, you know, I can't follow everything that the ACRS does but I think there were plans to brief the Committee on the results of that work. So it's just, from the discussion it sounds like that hadn't happen so I just wanted to raise that.

That there aren't many, or the results are, or the details of the results haven't been made public, as far as I can tell, but a sort of summary paper from 2022 did show that if you include external events that the NAI 18-04 threshold, frequency consequence threshold is actually exceeded for some event sequences.

So if you haven't been briefed on that study I'm curious why not, but I think it could shed some light on this discussion. Thank you.

CHAIR MARTIN: Okay, thank you very much for your comment. Certainly on this subject we'll be revisiting Reg Guide 1.183 both next month and in December. It's going to be kind of a regular thing. Obviously one of the important things we review.

MR. SNODDERLY: This is Mike Snodderly from the ACRS Staff. You know, just looking at our planning documents, the rainbow chart. So December 19th the Committee is scheduled to review Reg Guide 1.183 Rev 2. And then on January 14th, in the morning, we're scheduled to meet with the folks from Part 53 to hear an update on Part 53.

Which as Bill said, they expect the package to be sent out for public comment relatively soon. Hopefully on October 7th. But those will be, I think, important meetings.

MEMBER PETTI: There's also a November

16th meeting, source term --

MR. SNODDERLY: Yes.

MEMBER PETTI: 1.183. November --

(Simultaneously speaking.)

MR. SNODDERLY: Yes. And as Anders said, the DG-1414 I think there will be some discussion hopefully on that on January. You know, the committee will have an opportunity to ask questions --

CHAIR MARTIN: Absolutely.

MR. SNODDERLY: -- or to discuss it further. So, and I bring all that up to assist you, yes, as far as kind of next steps. And you're going to get other opportunities to look at this.

CHAIR MARTIN: Sure. Well, let's make sure, there is no last public comment, so we move into member discussion of course.

MR. SNODDERLY: Sorry.

CHAIR MARTIN: I'm not seeing hand raise, but, you know, five, four, three, two, one. Okay. We'll move to any member discussion, which we've kind of already started, but --

MEMBER PETTI: I defer because we only have five minutes. Some of us have a meeting at noon. I just wanted to thank the Staff, I thought this was really well done.

We've got so many new members on the Committee now, I think it was timely. Particularly as looking at the fact of the history, it just takes a huge amount of energy to reconstitute that so it's going to be a really useful presentation. We've got a couple new members coming on, it will be a required meeting I think.

(Laughter.)

CHAIR MARTIN: Yes. Again, thank you very much. Obviously this was setup to be an information meeting. A lot of information was conveyed. And I think it preps us for the next several meetings that we'll have on business and their subjects. Again, thank you very much.

Any further discussion that we want to jump into, other than the fact that there is a meeting at noon? Hearing none, we will adjourn the meeting. Thank you very much.

(Whereupon, the above-entitled matter went off the record at 11:56 a.m.)

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Advisory Committee on Reactor Safeguards

Thermal-Hydraulic Accident Analysis Subcommittee

Meeting on Accident Selection in Support of Emergency Planning and Siting Analyses

October 1, 2024

Outline

- Evolution of accident analyses and consideration of offsite consequences in support of:
  - Siting
  - Emergency preparedness

- Guidance on selection of accident scenarios for demonstrating general site suitability under 10 CFR Part 100

- Guidance to assess defense in depth and cliff-edge effects

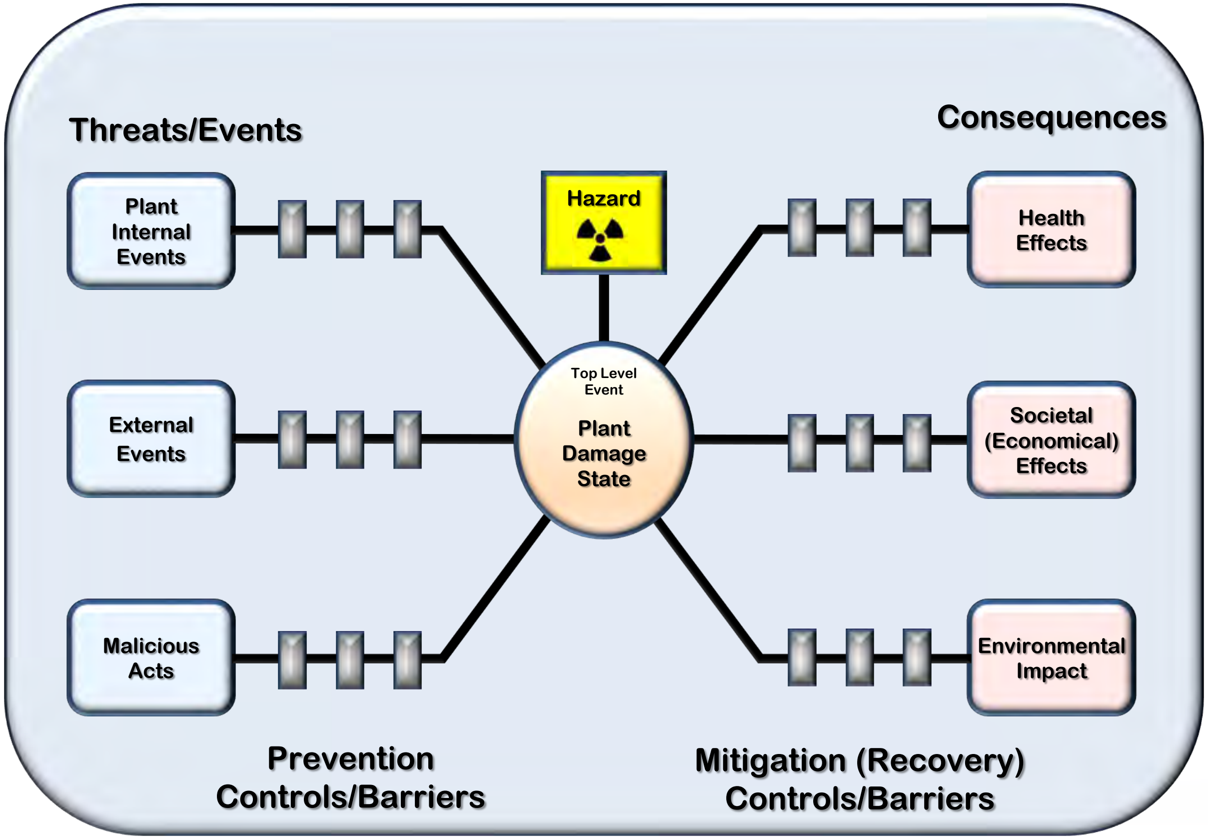
Overview – Consideration of Radiological Consequences in NRC Activities

- Routine (Anticipated) Effluents
  - 10 CFR Part 20
  - 10 CFR Part 50, Appendix I and 10 CFR 50.34a
- **Unplanned Events**
  - Safety Analyses (Chapter 15, w/ primary focus on barriers)
  - Design Basis Radiological Consequence Analyses ("Siting Analysis")
    - 10 CFR 100.21 (a) and (b); 10 CFR 50.34/52.79
  - Population Density Considerations (10 CFR 100.21(h))
  - Emergency Preparedness Considerations
  - Severe Accident Considerations
  - Safety Goals
  - Cost-Benefit Assessments

Overview – Consideration of:
Threats/Events, Prevention, Mitigation and Consequences

<u>"Traditional" Approach</u>
- Safety Analysis
  - o Challenges to barriers
- Siting/Containment
  - o Major Accident
- Severe Accidents
- Generic Analyses
  - o Population density
  - o EPZs

<u>Revised Approaches (e.g., LMP)</u>
- Safety Analysis
  - o LBEs (event sequences)
  - o Frequency-Consequence
- Siting/Containment
  - o LBEs (EAB/LPZ)
- Consequence assessment
  - o Population density
  - o EPZs

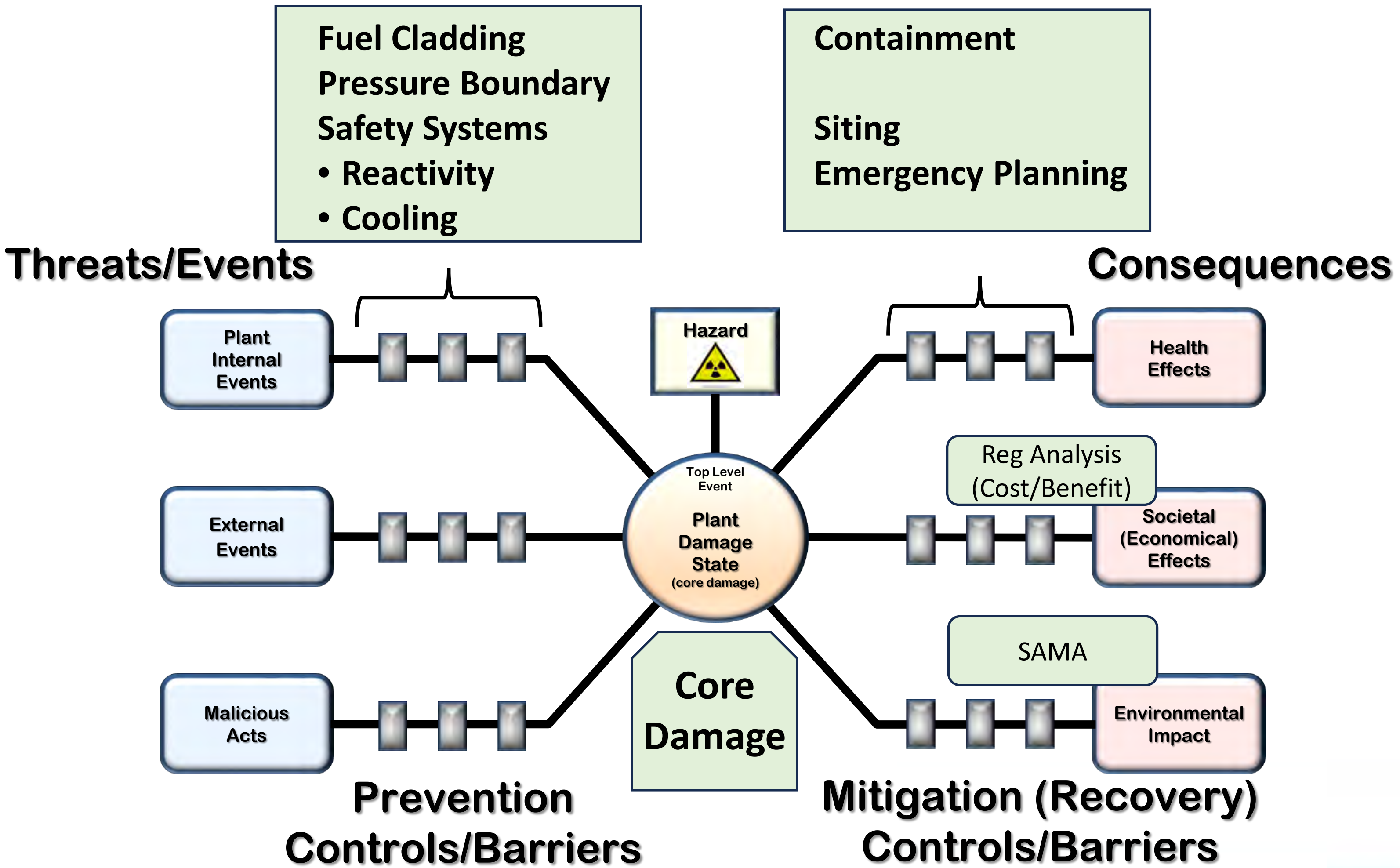


"Bowtie Diagram"

Evolution of “Traditional” Approaches

- Methodologies evolving since initial AEC/NRC approaches
  - Maximum Credible Accident/Design Basis Accident
  - “Class 9” Accidents
  - Reactor Safety Study
  - Three Mile Island
    - NUREG 0625, (Siting Policy Task Force)
    - Regulatory Guide 4.7, (General Site Suitability Criteria)
    - NUREG 0396, (NRC/ EPA Task Force on Emergency Planning)
    - Environmental Reviews
  - Commission Policy Statements
  - Risk-Informed, Performance-Based Initiatives
  - Advanced Reactors

Bowtie Representation (Traditional)



Overview – Consideration of Radiological Consequences in NRC Activities (Offsite Areas/Zones)

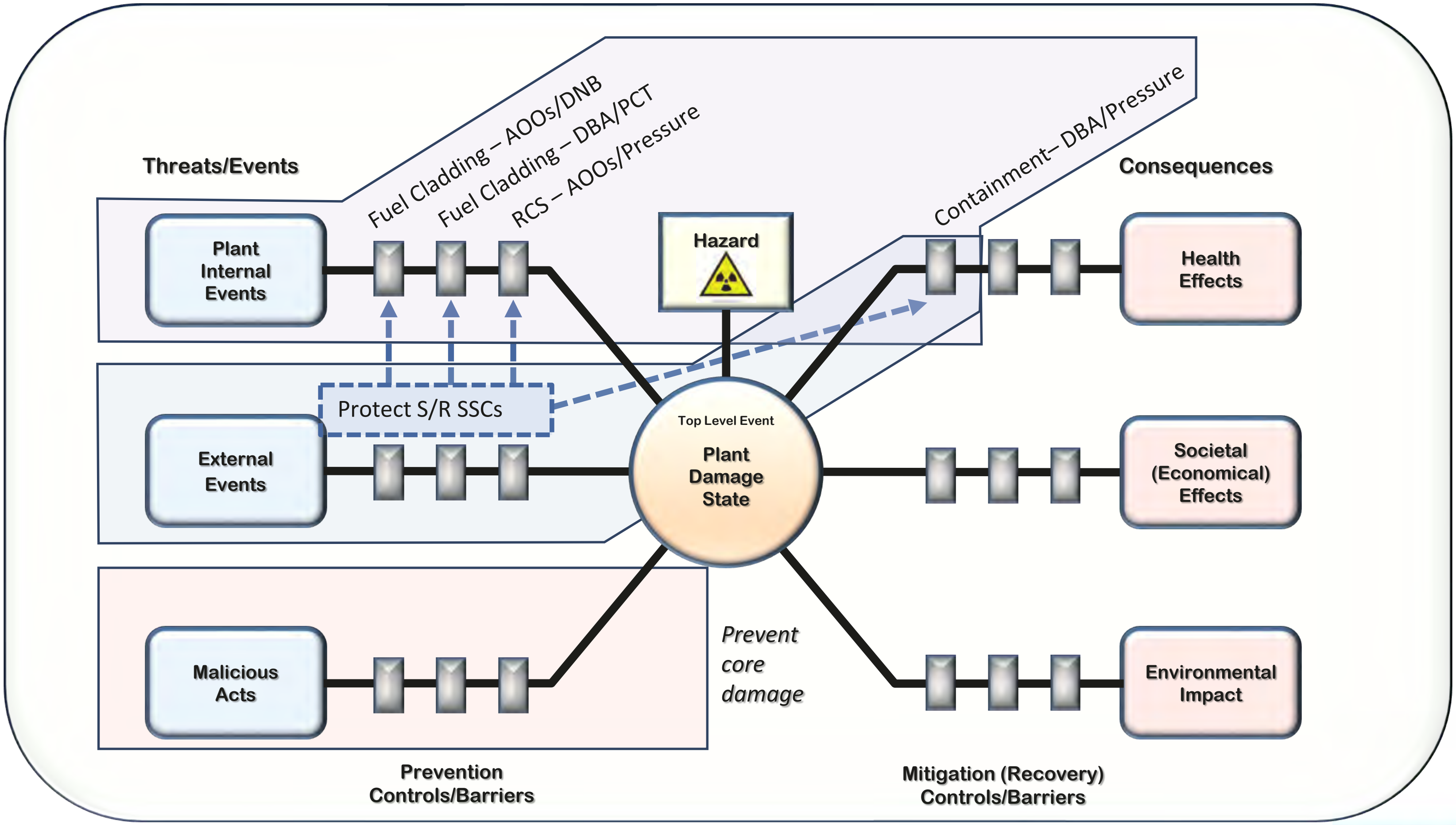
				Distance (Miles)
Routine Effluents	Design and Programs	Part 20		Unrestricted Areas
Unplanned Events	Siting and Design	100.21(a) 50.34/52.79	Exclusion Area Boundary	~0.5
			Low Population Zone	~4
		100.21(b)	Population Center Distance	~5
		100.21(h)	Population Density	20
	Emergency Planning	50.47	Emergency Planning Zone	10
	Safety Goals	QHO	Prompt	1
			Latent	10
	Regulatory Analysis	NUREG/BR-0058	Cost-benefit (population)	50

Recent & Ongoing Activities

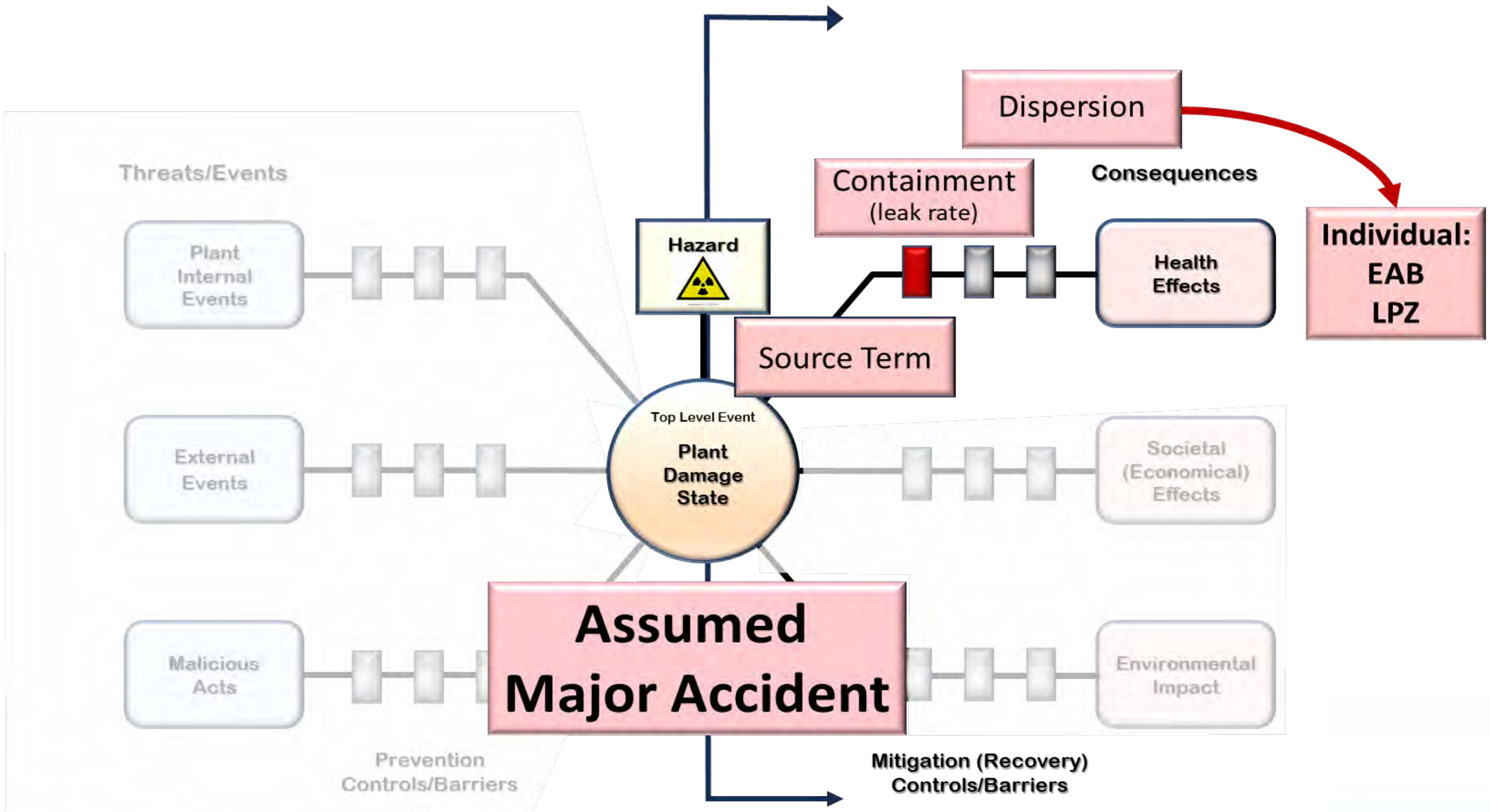
- ARCAP
- RG 1.183
- RG 4.7
- 10 CFR 50.160
  RG 1.242

ARCAP – Advanced Reactor Content of Applications Program (DANU-ISG-2022-01; RG 1.253)
RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors"
RG 4.7, "General Site Suitability for Nuclear Power Stations"
RG 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities"

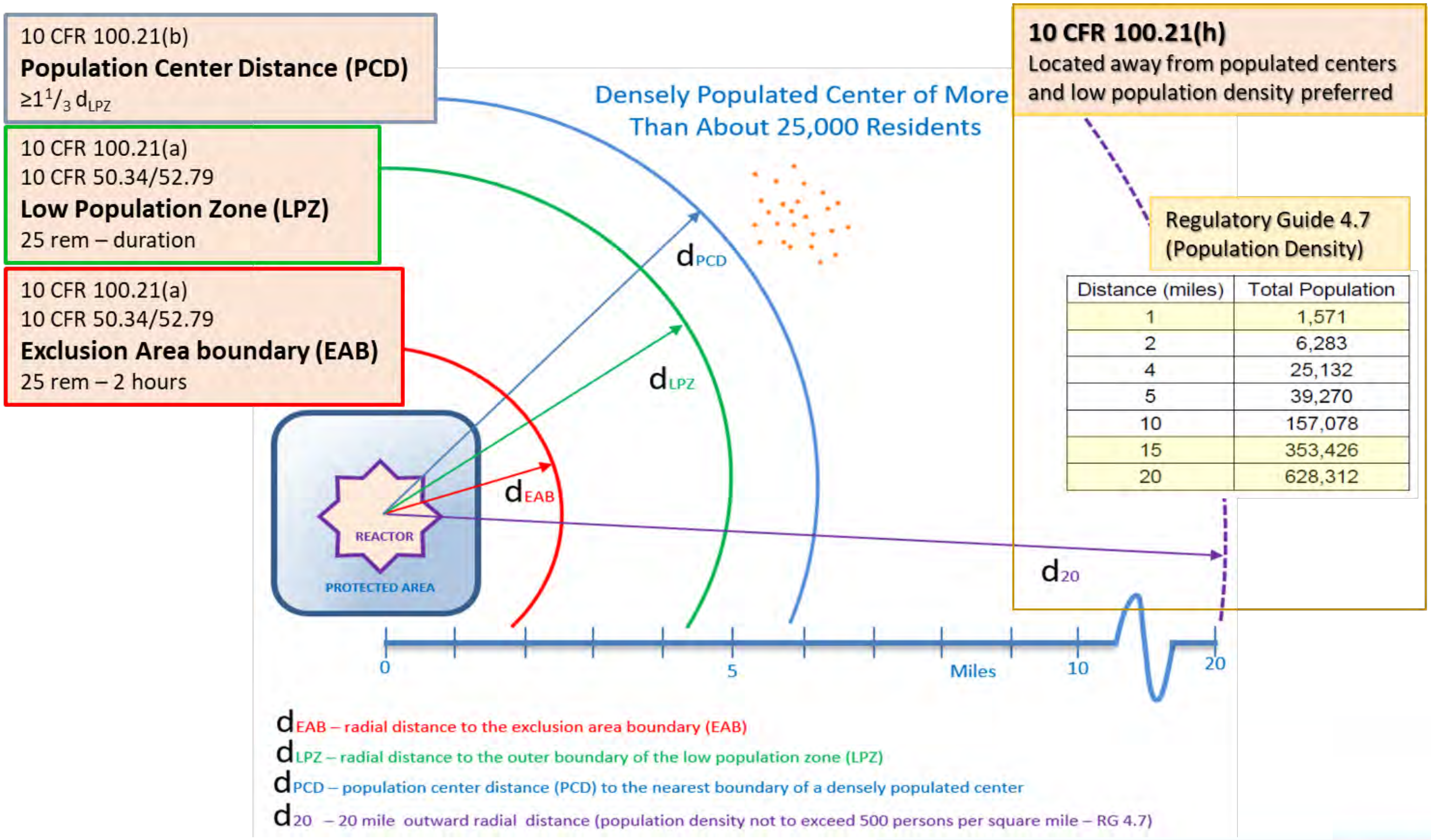
Traditional Safety Analyses (Chapter 15)



RG 1.183 - Design Basis Radiological Consequence Analyses ("Siting Analysis")

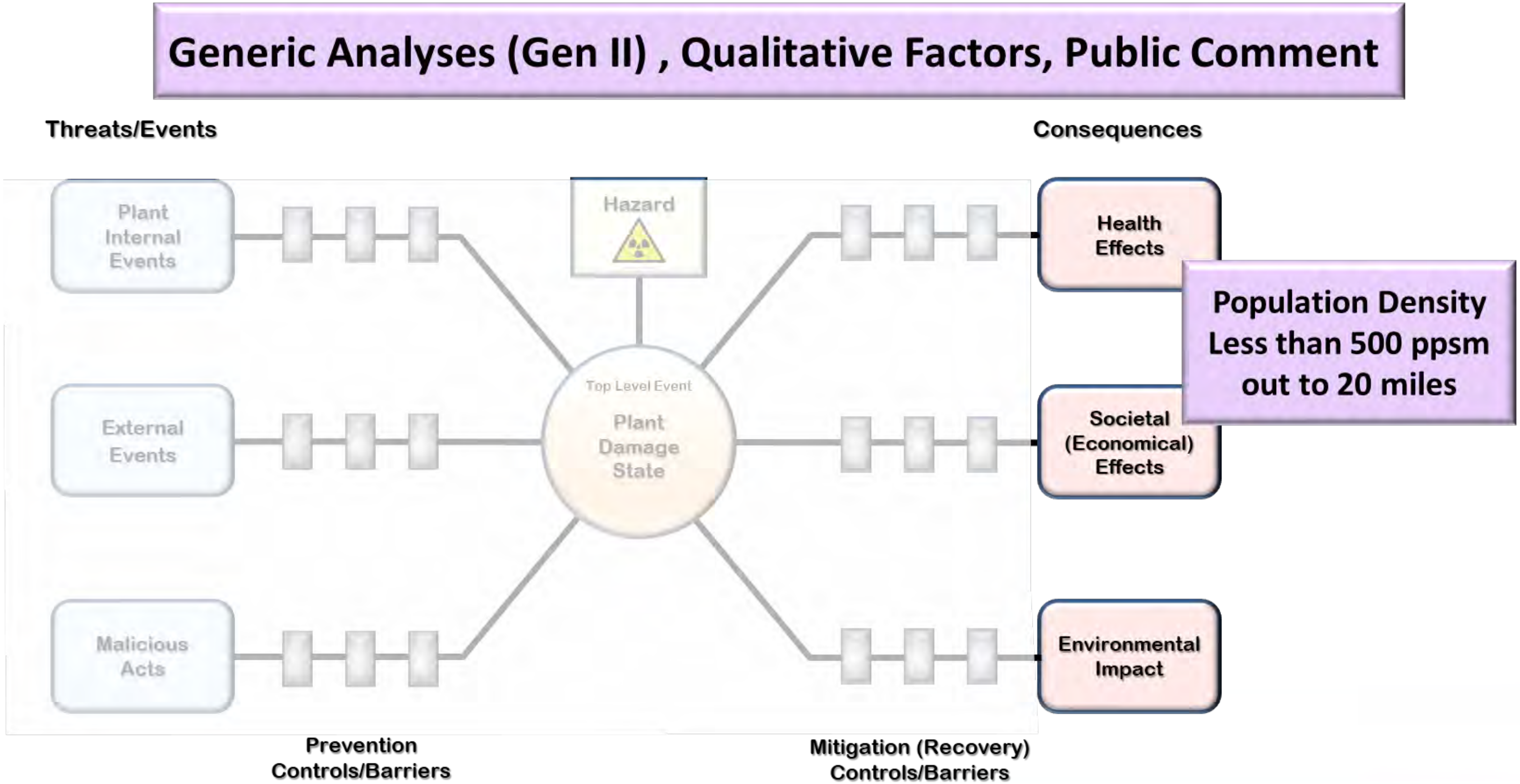


Design Basis Radiological Consequence Analyses ("Siting Analysis")



Distance (miles)	Total Population
1	1,571
2	6,283
4	25,132
5	39,270
10	157,078
15	353,426
20	628,312

Population Density Considerations



LWR Siting and Safety Analysis Radiological Consequence Analysis Guidance – Previous Methods

Whole body and thyroid dose figures of merit (FOM)

TID-14844 source term

Taken from 10 CFR 100.11 siting requirements

- Regulatory Guide (RG) 1.3, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors,“ Rev. 2 (June 1974) - Withdrawn
- RG 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors,“ Rev. 2 (June 1974) - Withdrawn
- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," several Chapter 15 sections for accident-specific analyses
- RG 1.195, "Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors," Rev. 0 (May 2003)

RG 1.183 Guidance

Total effective dose equivalent (TEDE) FOM
NUREG-1465 and SAND 2011-0128 source terms

- RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," Rev. 0 (July 2000)
- RG 1.183, Rev. 1 (October 2023)
- NUREG-0800, Chapter 15.0.1, "Radiological Consequence Analyses Using Alternative Source Terms" (July 2000)
- NUREG-0800, Chapter 15.0.3, "Design Basis Accident Radiological Consequence Analyses for Advanced Light Water Reactors" (March 2007)
- Draft Guide 1524, RG 1.183 draft Rev. 2, being developed for Increased Enrichment Rulemaking efforts

Accident Consequence Figures of Merit Based in Regulation

Exclusion Area Boundary –

An individual located at any point on the boundary of the exclusion area for any 2-hour period following the onset of the postulated fission product release, would not receive a radiation dose in excess of 25 rem TEDE.

Low Population Zone –

An individual located at any point on the outer boundary of the low population zone, who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage), would not receive a radiation dose in excess of 25 rem TEDE.

Control Room –

Adequate radiation protection is provided to permit access to and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem TEDE for the duration of the accident.

RG 1.183 Figures of Merit

Accident-specific offsite dose acceptance criteria

- –Based on NUREG-0800
- –Graded based on relative qualitative likelihood

Full regulatory dose value – 25 rem TEDE	Maximum hypothetical accident, lowest likelihood
Well within (25%) – 6.3 rem TEDE	Low relative likelihood
Small fraction of (10%) – 2.5 rem TEDE	Highest relative likelihood

RG 1.183 Analysis Approach

The DBAs were not intended to be actual event sequences but, rather, were intended to be surrogates to enable deterministic evaluation of the response of the plant engineered safety features. These accident analyses are intentionally conservative in order to address uncertainties in accident progression, fission product transport, and atmospheric dispersion.

Traditional deterministic radiological consequence analyses

- 95th percentile meteorology, no protective actions, no dry-deposition, etc.
- Source term is risk-informed
- Modeling generally does not credit facility features that:
  - are not safety-related;
  - are not covered by technical specifications;
  - do not meet single-failure criteria, or;
  - rely on the availability of offsite power. Design basis delays in actuation of these features should be considered, especially for those features that rely on manual operator intervention.

Radiological emergency preparedness (EP)—

- *ensures protective actions can and will be taken*
- *is an independent layer of defense in depth*
- *provides dose savings*
- *is risk-informed*

EP is a matter of judgment

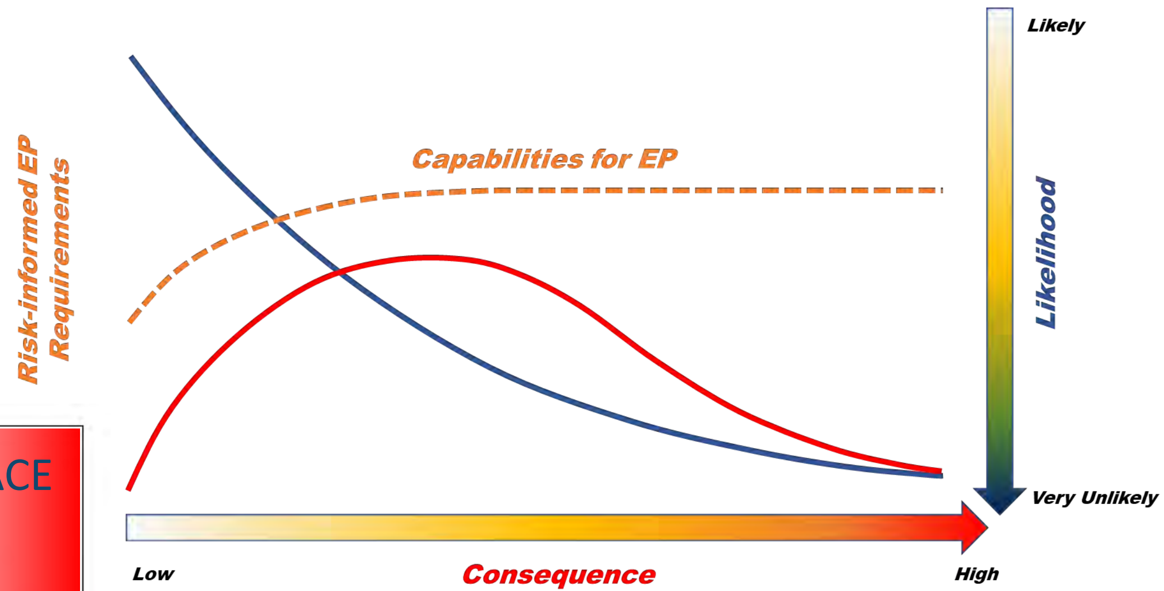
"Regulation does not require dedication of resources to handle every possible accident that can be imagined. The concept of the regulation is that there should be core planning with sufficient planning flexibility to develop reasonable response to those very serious low probability accidents which could affect the public."

[SONGS CLI-83-10, 17 NRC 528, (1983)]

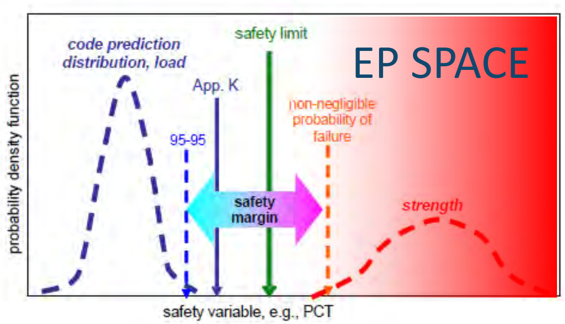
"A reading of the Report [NUREG-0396] indicates clearly that the margins of safety provided by the recommended 10-mile radius were not calculated in any precise fashion but were qualitatively found adequate ***as a matter of judgment***."

[55 FR 5605, Feb 16, 1990]

EP has different use for risk information



RIPB EP



RIPB Design

RIPB EP ≠ RIPB Design

RIPB: risk-informed, performance-based

U.S.NRC
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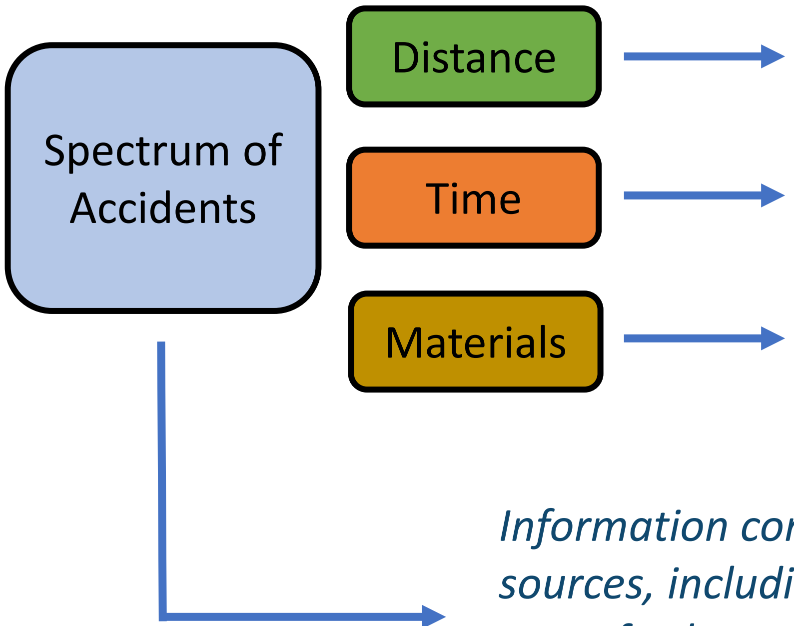
Protecting People and the Environment

The planning basis informs the planning

Planning Basis | **Emergency Planning Functions and Elements**



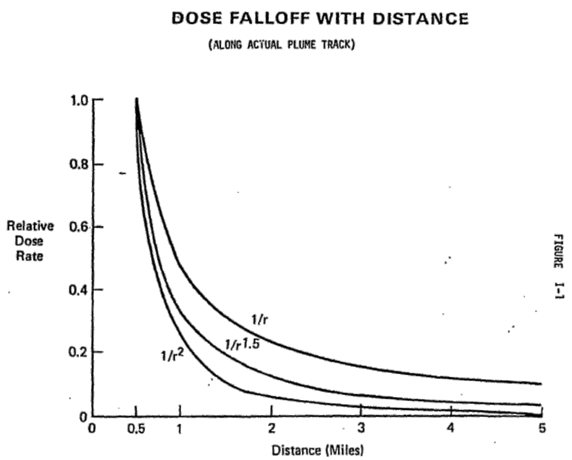
Distance → EPZ, exposure pathways, protective measures, communication, assessment

Time → Timeliness of classification and notification, protective measures, communication, EPZ

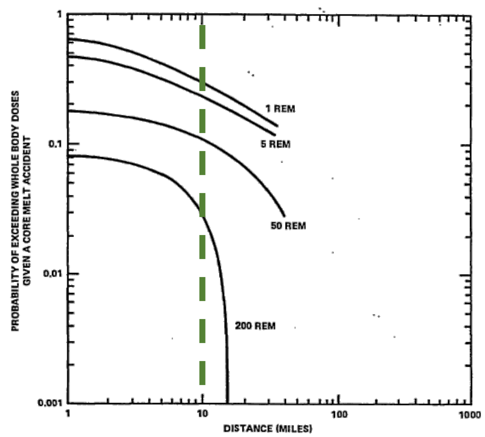
Materials → Detection and assessment capabilities, radiological protection, protective measures

Information comes from many quantitative and qualitative sources, including, but not limited to, licensing basis events, acts of sabotage, contiguous hazards, environmental reports, consequence analyses, real events

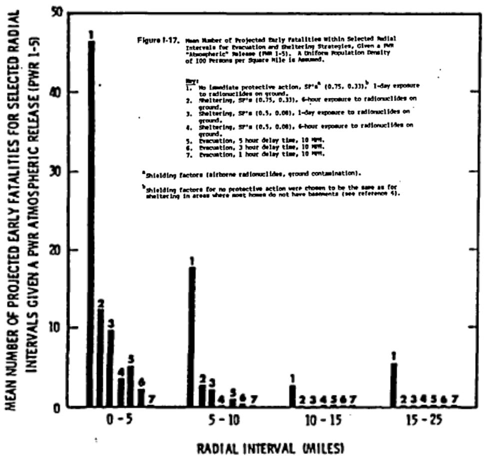
The EPZ is risk-informed



Design Basis Accidents



Beyond Design Basis



Effectiveness of Protective Measures

NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants," November 1978

EP is independent of probability

The NRC policy statement, “Safety Goals for the Operation of Nuclear Power Plants” (51 FR 30028; August 4, 1986), states that emergency preparedness is a “defense-in-depth measure.”

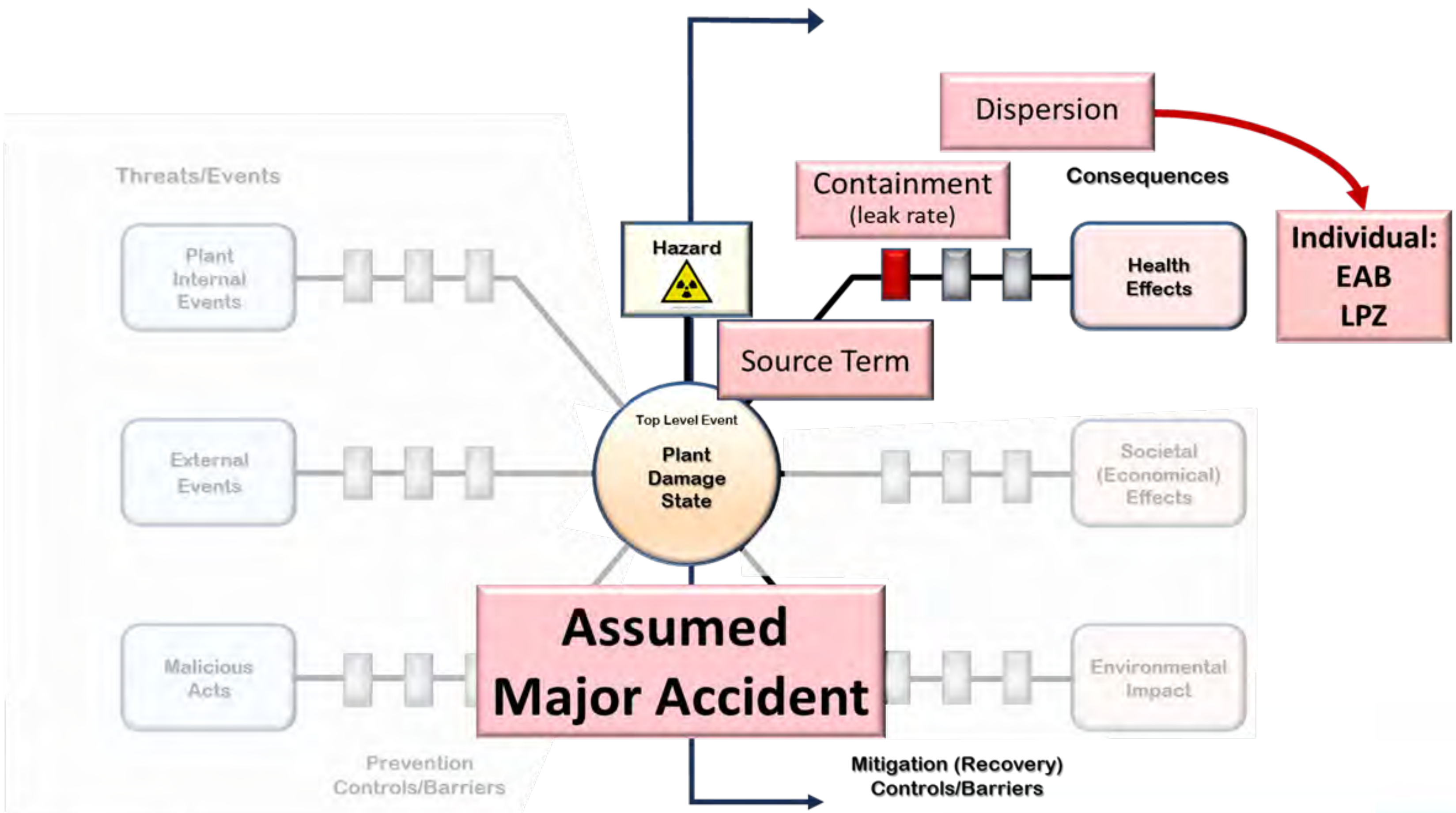
Emergency preparedness is carried out as a matter of prudence rather than in response to a quantitative analysis of accident probabilities. The effectiveness of an emergency plan is independent of probability.

[RG 1.219, Revision 1, dated July 2016]

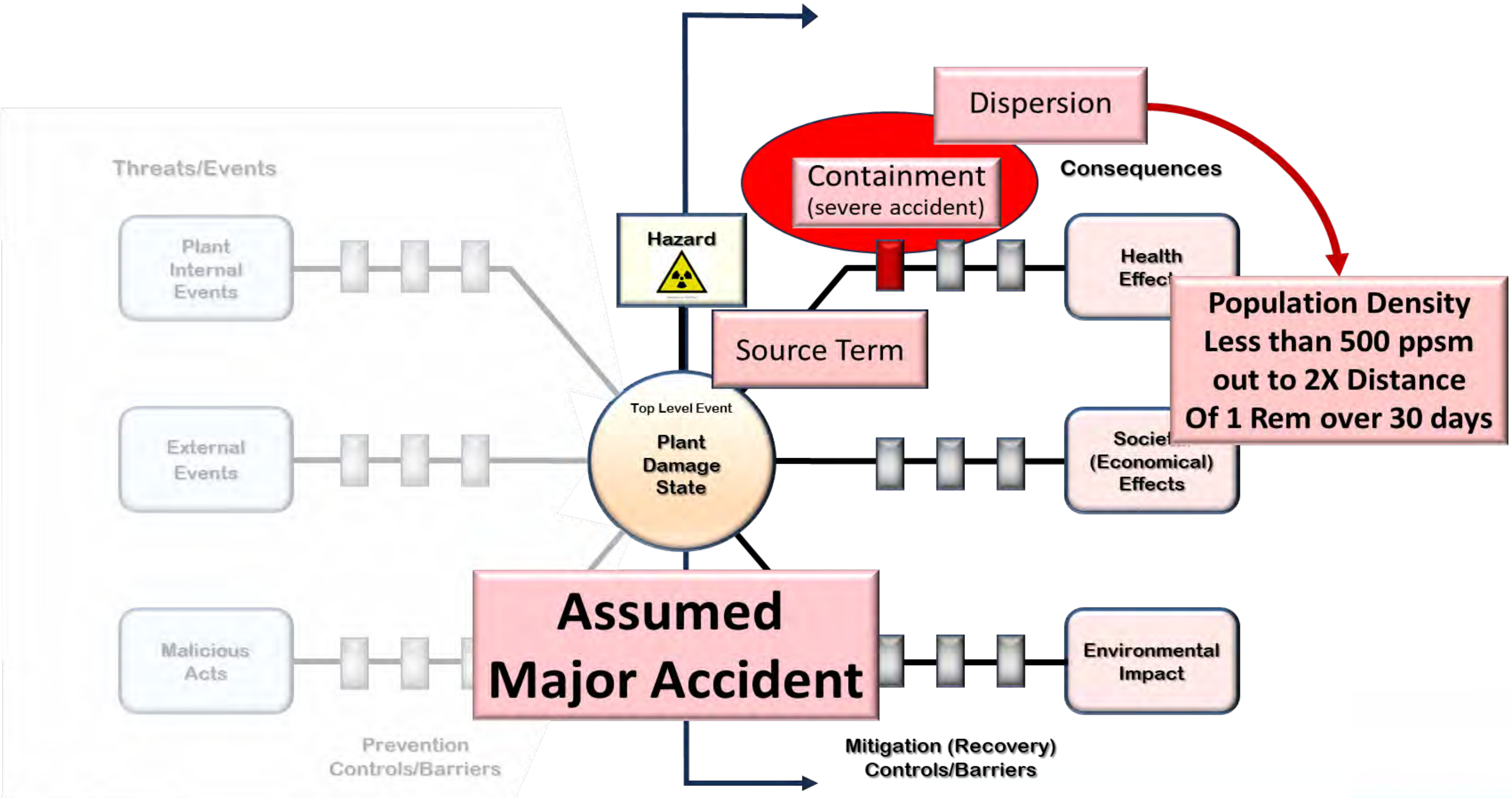
Guidance on selection of accident scenarios for demonstrating general site suitability under 10 CFR Part 100 (RG 4.7, Rev 4)

- Light-Water Reactors
  - Determination/Confirmation of EAB/LPZ
  - Population density assessment
    - 20 miles
    - Alternative Determination
- Non-LWRs Licensing Modernization Project
  - Determination/Confirmation of EAB/LPZ
  - Population density assessment
    - 20 miles
    - Alternative Determination
- Non-LWRs not using LMP Approach

Traditional Determination/Confirmation of EAB/LPZ (LWRs) [Slide 9]



RG 4.7 Rev 4 “Traditional/LWR” Consideration of Population Density as Alternative to 20 miles



Regulatory Guide 4.7, Revision 4 Functional Containment (LMP)

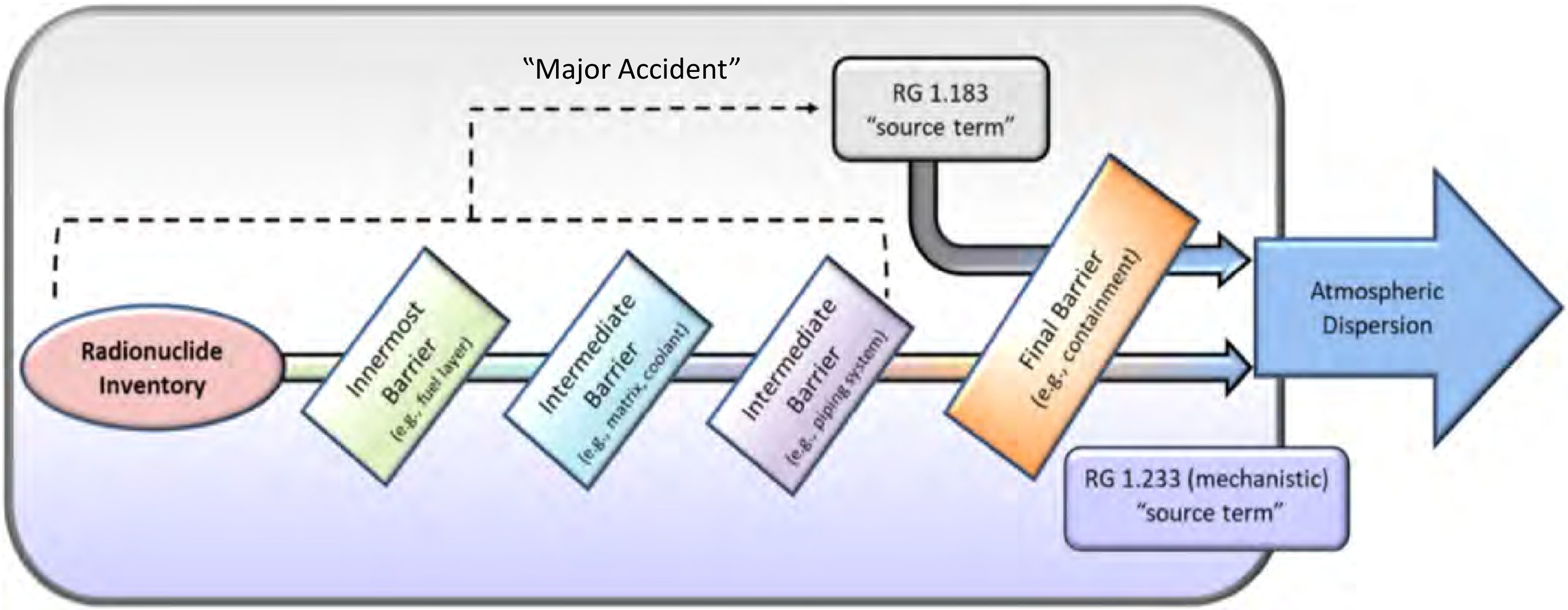
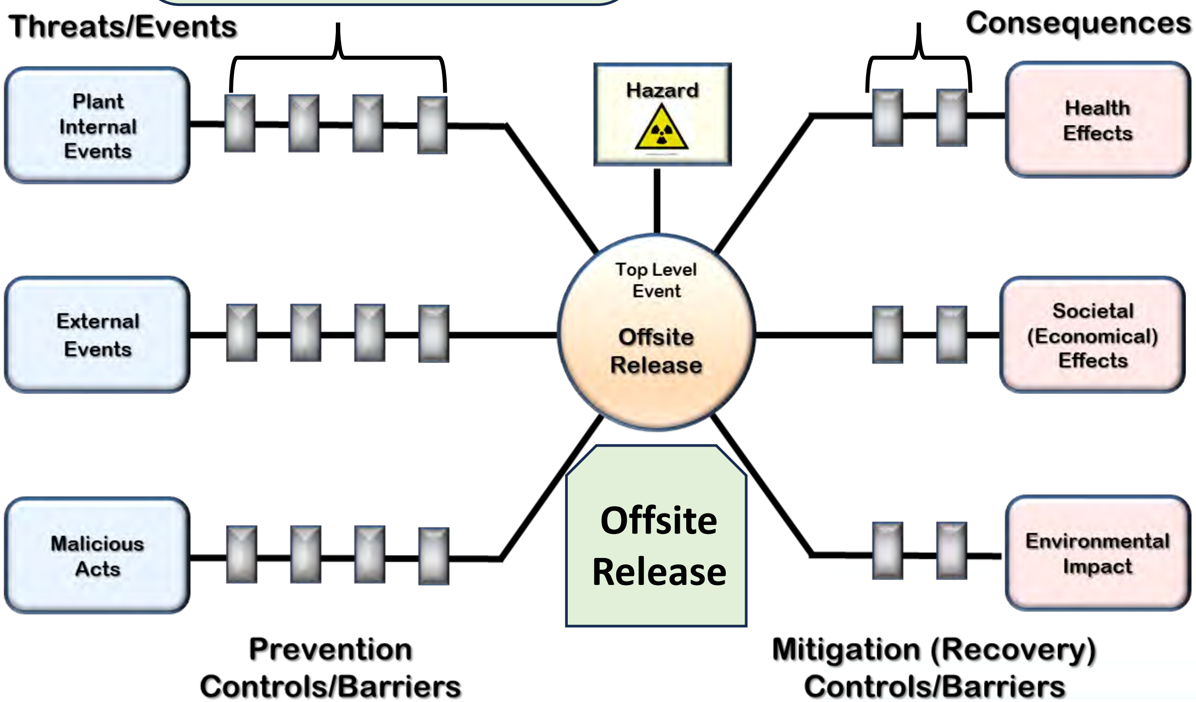


Figure 1: Approaches for estimating radiological releases (RG 4.7, Rev. 4, Appendix A)

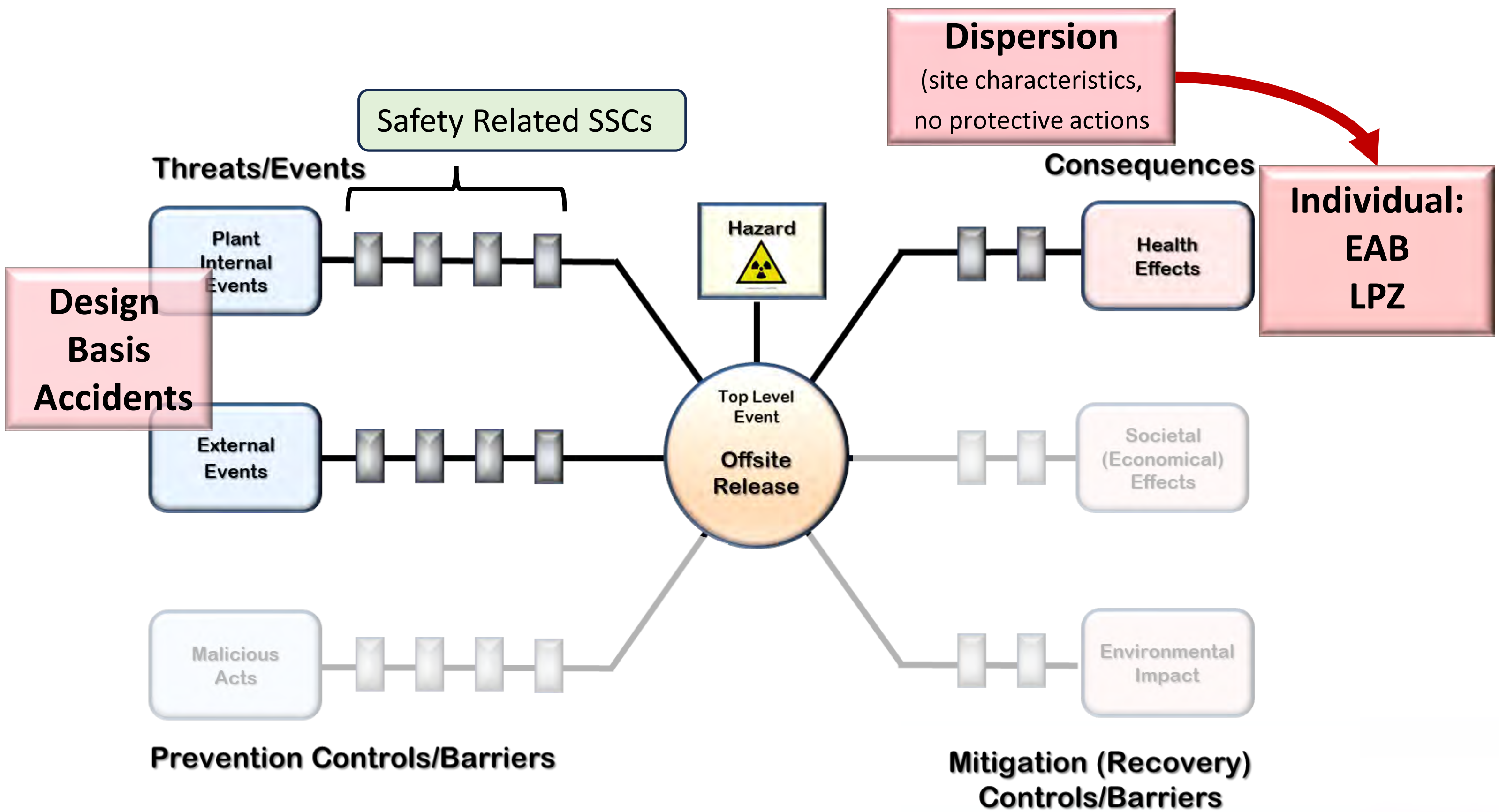
Licensing Modernization Project
Mechanistic Source Term

Safety Functions
- Reactivity
- Cooling
- Containment (functional)

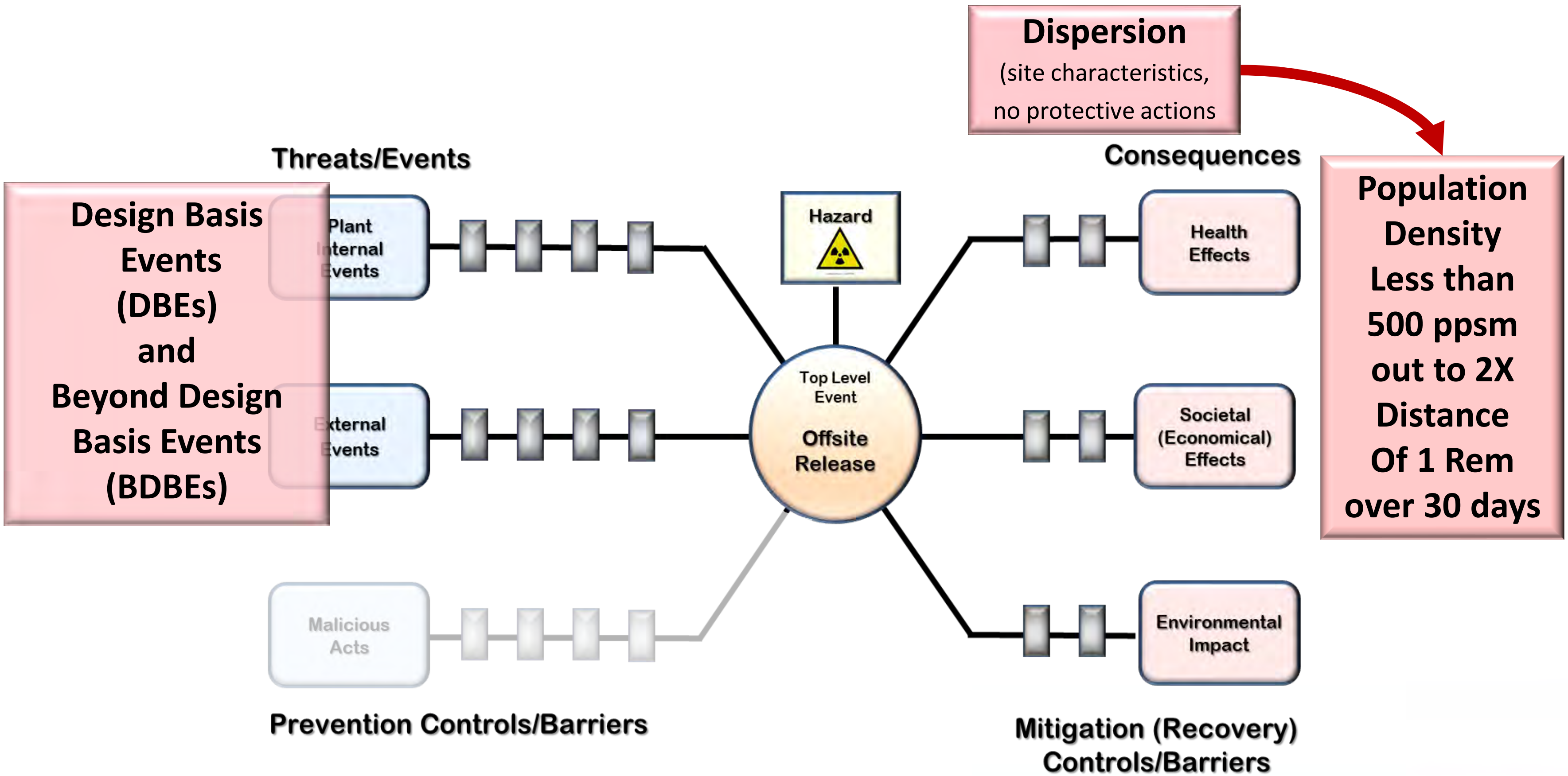
Siting
Emergency Planning



LMP Determination/Confirmation of EAB/LPZ

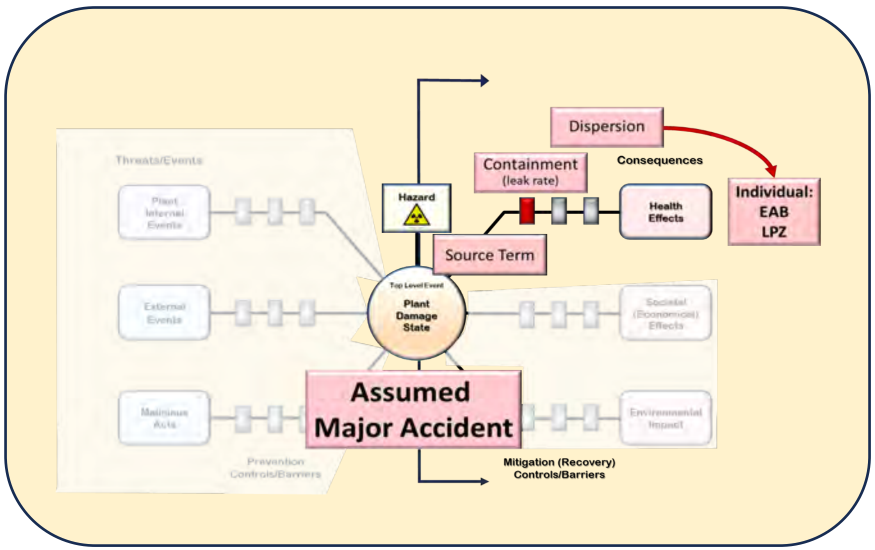


Licensing Modernization Project
Assessment of Population Density

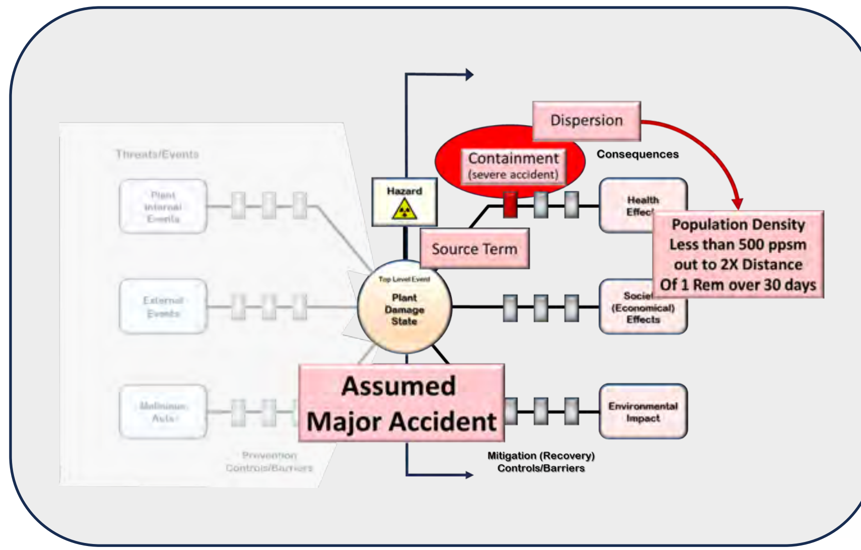


Non-Light-Water Reactor <u>not</u> using LMP

- Same approach as for LWRs (Slides 21/22)
- Challenge – no defined “source term” for radionuclides introduced into containment for a “major accident”



Confirmation of EAB/LPZ



Population Density Considerations

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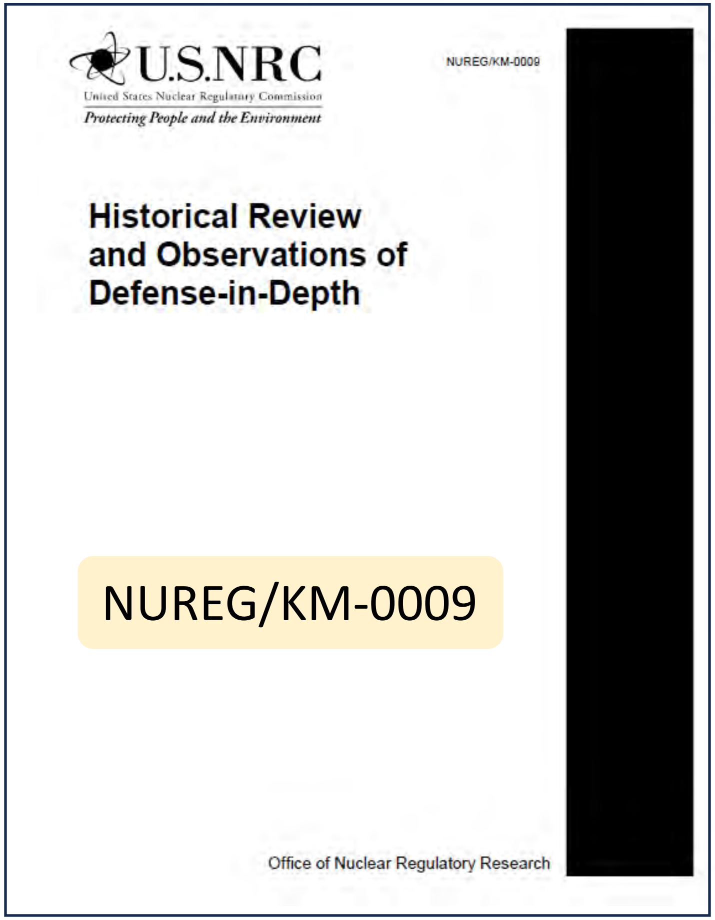
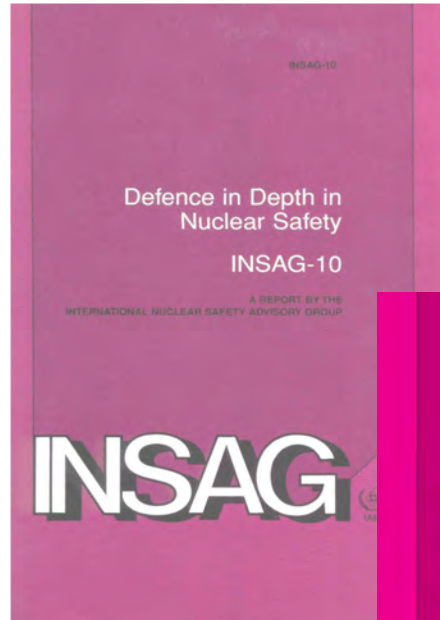
United States Nuclear Regulatory Commission
Protecting People and the Environment

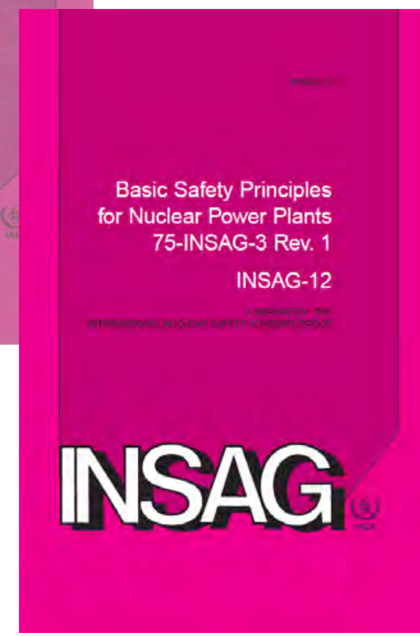
Defense in Depth
and
Cliff-Edge Effects

Defense in Depth - Background



NUREG/KM-0009





INSAG-10
INSAG-12

Assessing Defense in depth

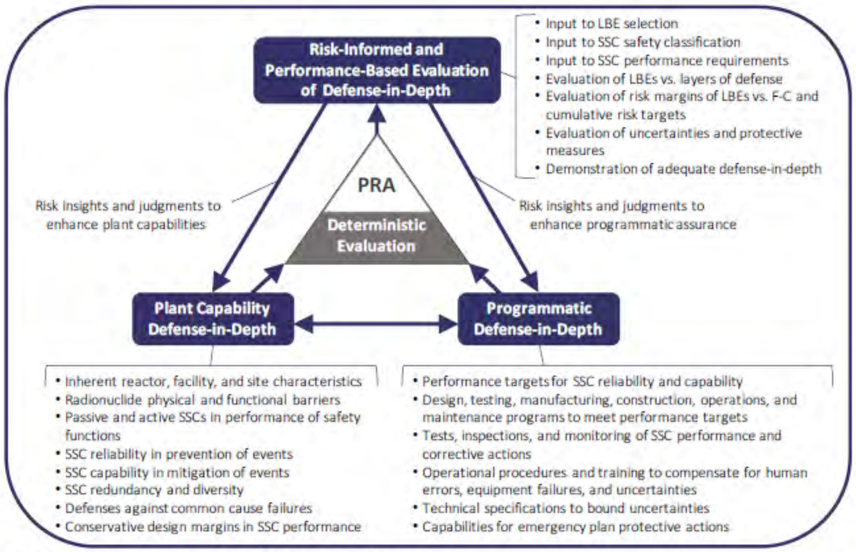


Figure 5-2. Framework for Establishing DID Adequacy

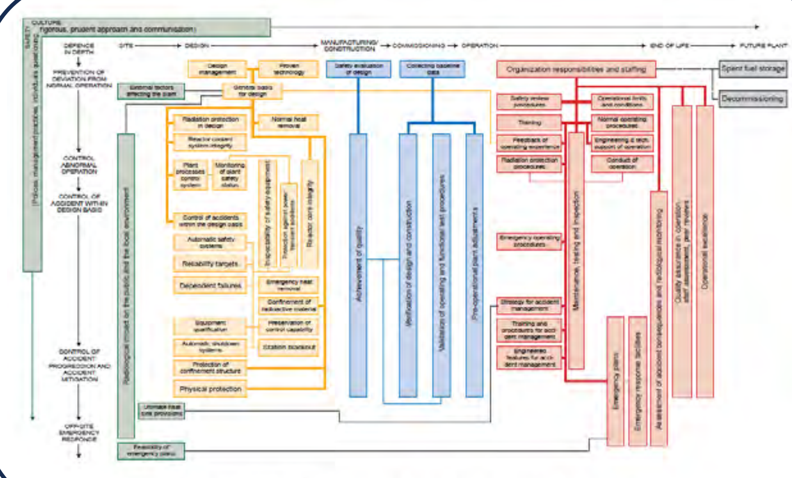


FIG. 2. Schematic presentation of the INSAG specific safety principles showing their coherence and their interrelations.

NEI 18-04

- Plant Capability Defense in Depth
- Programmatic Defense in Depth
- RIPB Assessments

INSAG-12

- Defence in Depth (5 Levels)
- Plant Operational State
- Prevention and Mitigation

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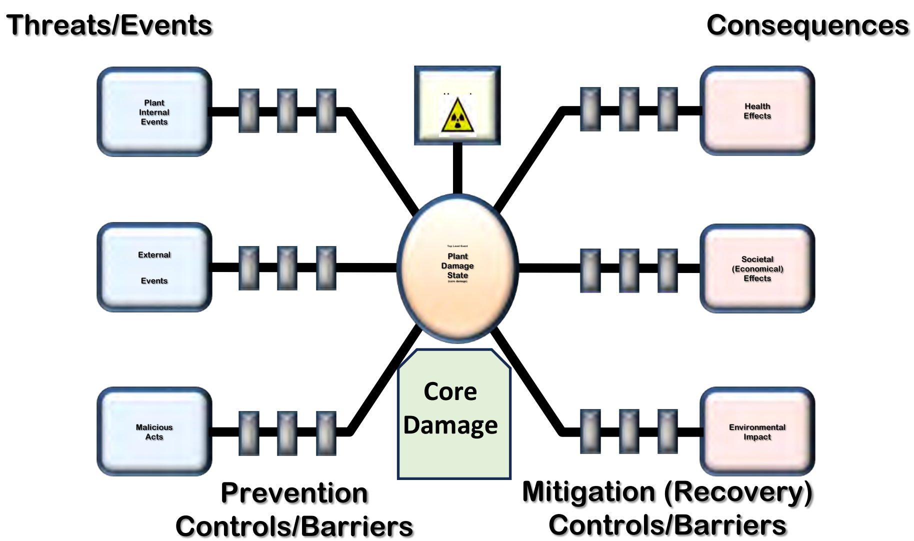
Protecting People and the Environment

Defense in depth – traditional discussions



- Different Contexts
  - Plant Level
    - Barriers
    - Controls
  - Fire Protection
  - Security
- Prevention & Mitigation often related to top level event (core damage)
  - IAEA INSAG-12
  - Reg Guide 1.174
    - Changes to licensing basis

Defense in depth - LMP

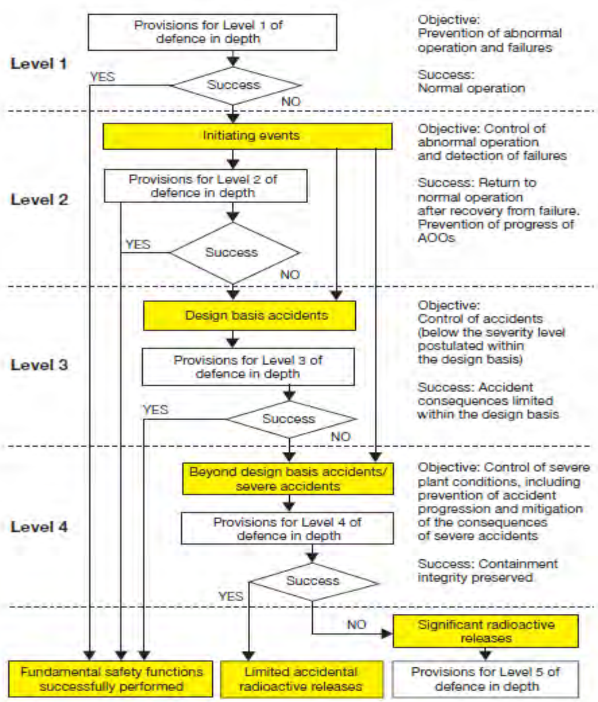


FIG. 1. Flow chart for defence in depth.

IAEA Safety Report Series No. 46
Assessment of Defence in Depth
for Nuclear Power Plants
(Similar to NEI 18-04)

LMP Approach

- Higher levels mitigate failure of prevention by lower levels
  - o e.g., Mitigation of a DBE to address failure to mitigate an AOO
- LBE Evaluations
  - o Frequency/Consequence
- Cumulative risk
  - o Safety Goals
- No single design or operational feature, no matter how robust, is exclusively relied upon to satisfy the five layers of defense

Cliff Edge Effects
Background

IAEA SSR 2/1

- A 'cliff edge effect', in a nuclear power plant, is an instance of severely abnormal plant behaviour caused by an abrupt transition from one plant status to another following a small deviation in a plant parameter, and thus a sudden large variation in plant conditions in response to a small variation in an input.
  - External Hazards
    - 5.21. The design of the plant shall provide for an adequate margin to protect items important to safety against levels of external hazards to be considered for design, derived from the hazard evaluation for the site, and to avoid cliff edge effects.

Cliff Edge Effects
Incorporation into Requirements & Guidance

10 CFR 50.155, "Mitigation of beyond-design-basis events."

RG 1.226, "Flexible Mitigation Strategies for Beyond-Design-Basis Events"

Sections 50.155(b) and (b)(1) require that applicants or licensees develop and implement strategies and guidelines to mitigate beyond-design-basis external events from natural phenomena that result in a loss of all alternating current power concurrent with either a loss of normal access to the ultimate heat sink (LUHS) or, for nuclear power plants with passive reactor designs, a loss of normal access to the normal heat sink. This section of the RG addresses developing and implementing the strategies and guidelines, and section C.4 addresses maintenance of the strategies and guidelines.

Cliff Edge Effects
Incorporation into Requirements and Guidance

NEI 18-04

- Event sequences with frequencies less than 5×10-7/plant-year are retained in the PRA results and used to confirm there are no cliff edge effects. They may also be taken into account in the RIPB evaluation of defense-in-depth.
- The evaluation of LBEs during the IDP [integrated decision-making process] will focus on the following questions:

  * * *

  Has the PRA evaluation provided an adequate assessment of "cliff edge effects?"

ASME/ANS RA-S-1.4-2021

- Cliff edge effect: an instance of a sudden large variation in plant conditions in response to a small variation in an input (e.g., change in flood height, grid perturbation based on voltage or frequency exceeding a breaker trip set point).

Cliff Edge Effects
Incorporation into Guidance

LIC-504, "Integrated Risk-Informed Decision-Making Process for Emergent Issues"

… Additionally, an assessment of potential cliff-edge effect resulting from the emergent condition may help focus decisions. In 2018, the International Atomic Energy Agency, in its "Terminology Used in Nuclear Safety and Radiation Protection," defined a cliff-edge effect … Extreme flooding scenarios and available physical margin used in the NRC's post Fukushima work used in previous LIC-504 assessments serve as an illustrative example of a cliff edge assessment. Another example may involve post-accident combustible gas sources, if the identified degraded condition involves increased post-accident combustible gas that exceeds detonation limits that may fail the reactor containment barrier.

Discussion

Acronyms & Abbreviations

AEC	Atomic Energy Commission
ANS	American Nuclear Society
AOO	Anticipated Operational Occurrence
ARCAP	Advanced Reactor Content of Application Project
ASME	American Society of Mechanical Engineers
BDBE	Beyond-Design-Basis Event (LMP)
CFR	Code of Federal Regulations
DBA	Design Basis Accident
DBE	Design-Basis Event (LMP)
DNB	Departure from Nucleate Boiling
EAB	Exclusion Area Boundary
EP	Emergency Preparedness
EPA	Environmental Protection Agency
EPZ	Emergency Planning Zone
FOM	Figure of Merit
FR	Federal Register
IAEA	International Atomic Energy Agency
IDP	Integrated Decisionmaking Process
LBE	Licensing Basis Event
LMP	Licensing Modernization Project
LPZ	Low Population Zone
LWR	Light-Water Reactor
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
PCD	Population Center Distance
PCT	Peak Clad Temperature
PPSM	Persons Per Square Mile
PRA	Probabilistic Risk Assessment
RCS	Reactor Coolant System
RG	Regulatory Guide
RIPB	Risk Informed, Performance Based
S/R	Safety Related
SAMA	Severe Accident Mitigation Alternatives
SSCs	Structure, Systems, and Components
TEDE	Total Effective Dose Equivalent
TID	Technical Information Division (AEC)

Attendance for ACRS Thermal-Hydraulic Subcommittee Meeting on October 1, 2024

Michael Snodderly
Larry Burkhart
Thomas Dashiell
Jana Bergman
Tyesha Bush
James Cordes - Court Reporter
Shandeth Walton
Jan Mazza
Anders Gilbertson (He/Him/His)
Dennis Bley
Stephen Schultz
Vesna B Dimitrijevic
Tammy Skov
Tracy Radel (She/Her)
Zach Gran
Tim Polich (Unverified)
Kevin Hsueh
Derek Widmayer
Hanh Phan
Jeffrey Herrera
Chris Courtenay (TerraPower)
Jeremiah Doyle (NuScale)
Robert Martin (He/Him)
Ron Markovich
Hovhannes Hovhannisyan
Monica Ray
Kyle Clavier
Brian Johnson (TerraPower)
Chris Forrest (TP)
Tiffany Long (She/Her)
Gregory Halnon
David Garmon
Nazila Tehrani (She/Her)
Hossein Nourbakhsh
John Biersdorf