Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	Advisory Committee on Reactor Safeguards Radiation Protection Subcommittee
Docket Number:	(n/a)
Location:	teleconference
Date:	Friday, November 17, 2023
Work Order No.:	NRC-2629 Pages 1-160

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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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RADIATION PROTECTION SUBCOMMITTEE

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FRIDAY, NOVEMBER 17, 2023

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The Subcommittee met in a Hybrid Meeting, In-Person and via Video-Teleconference, at 8:30 a.m. EST, Ron Ballinger, Chairman, presiding.

SUBCOMMITTEE MEMBERS:

JOY L. REMPE, Chairman
WALTER L. KIRCHNER, Vice Chairman
DAVID A. PETTI, Member-at-Large
RONALD G. BALLINGER, Member
VICKI M. BIER, Member
CHARLES H. BROWN, JR. Member
GREGORY H. HALNON, Member
JOSE MARCH-LEUBA, Member
ROBERT P. MARTIN, Member
THOMAS E. ROBERTS, Member
MATTHEW W. SUNSERI, Member

ACRS CONSULTANT:

DENNIS BLEY

STEVE SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

ALSO PRESENT:

HAROLD ADKINS, PNNL

GARILL COLES, PNNL

JEFF ENGLAND, NAC International

DANIEL FORSYTH, NRC

SHANA HELTON, NRC

STEVE MAHERAS, PNNL

JONATHAN MARCANO, NRC

TIM McCARTIN, NRC

VIRGIL PEOPLES, INL

STEVE SHORT, PNNL

BRIAN WAGNER, NRC

JEFF WAKSMAN, SCO

BERNARD WHITE, NRC

AGENDA

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Adjourn

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

8:30 a.m.

CHAIRMAN BALLINGER: The meeting will now come to order. This is a meeting of the Radiation Protection Subcommittee of the Advisory Committee on Reactor Safeguards. I'm Ron Ballinger, chairman of today's subcommittee meeting.

ACRS members in attendance are Charlie Brown, Greg Halnon, Bob Martin, Vicki Bier, Joy Rempe, Dave Petti, Tom Roberts. Let's see -- a line. I'm guessing that Matt Sunseri will be here, Jose March --

MEMBER SUNSERI: Yes, I'm on.

CHAIRMAN BALLINGER: Good, thank you. Jose March-Leuba and --

MEMBER MARCH-LEUBA: Yes, I'm here.

CHAIRMAN BALLINGER: Great. We have our consultant, Steve Schultz, and I believe Dennis Bley, am I right?

MEMBER KIRCHNER: And Ron, this is Walt. I'm here as well.

CHAIRMAN BALLINGER: Oh, wonderful, and Walt Kirchner. Thank you. Vesna is sick this morning, so she won't -- yeah. Okay, Chris Brown is the designated federal official for the meeting. He's around here somewhere.

During today's meeting, the subcommittee will receive a briefing on risk-informed methodology for a transportable micro-reactor package. The subcommittee will hear presentations by and hold discussions with the NRC staff, PNNL and its contractors, and other interested persons regarding this matter.

Let's say a little bit more about this. This meeting is for an information meeting only unless we decide to write a letter, which is not up to me. Also, personally, I believe that if you were to take the word Pele out of this document, the PNNL document, and substitute any other micro-reactor, or spent nuclear fuel for that matter, this document or this methodology would be equally appropriate, and so I think what we're going to hear about today is a methodology which is a much broader application than for Pele.

The rules for participation in all ACRS meetings were announced in the Federal Register on June 13, 2019. The U.S. NRC public website provides the ACRS charter, bylaws, agendas, letter reports, and full transcripts of all full and subcommittee meetings, including slides.

The ACRS only speaks through its published letter reports. The agenda for this meeting was posted on the NRC website along with an MS Teams link. We have received no written statements or requests to make an oral statement from the public.

Today, the subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate. A transcript of the meeting is being kept and will be made available.

Today's meeting is being held over Microsoft Teams, as I mentioned. There is also a telephone bridge line, as well as a link allowing participation of the public.

When addressing the subcommittee, the participants should first identify themselves and speak with sufficient clarity and volume so that they may be readily heard. When not speaking, we request that participants mute your computer microphone or phone by pressing star-6. Otherwise, we'll get feedback in here, which will be disruptive. We remind participants not to use the chat feature to answer questions or make comments.

Before we start, three members have been identified as having conflict of interest. Members Petti, Sunseri, and Martin have been identified as having a conflict of interest, so they can be here, but not participate in the deliberation. We'll now proceed with the meeting and start by --

MEMBER SUNSERI: Hey, Ron. This is Matt. I have not declared a conflict of interest. I don't have one.

CHAIRMAN BALLINGER: Sorry, no, okay, cross that off, great, okay. That's my second mistake so far today. There will be many. Okay, we'll now proceed with the meeting and start by calling on Shana Helton, director of the Division of Fuel Management, NMSS, for opening remarks. Shana?

MS. HELTON: Thank you very much, and I really appreciate the opportunity for you to hear from our staff today.

CHAIRMAN BALLINGER: Shana, you've got to almost swallow the mic.

MS. HELTON: Do I have to like -- okay, sorry. Is this better, sound better?

CHAIRMAN BALLINGER: Yeah.

MS. HELTON: Okay, great. Thank you. Thanks for the opportunity to be here today. I'm really excited for you to hear from our staff who have been working so hard on this Project Pele. This has been a really high priority for NMSS and for our division as we continue to fulfill our regulatory role, and as we support the nation's development of this advanced technology.

Bernie will discuss the details of the NRC's role in this project, and before I turn it over to him and others at the table, I'd like to recognize the NRC staff who have also been performing the review and assisting in drafting and editing the endorsement letter and method evaluation, including Brian Wagner, Tim McCartin, Juan Lopez, Loren Howe, Chris Bajwa, Dan Forsyth, Drew Barton, Jeremy Tapp, and others from -- those are all in the Division of Fuel Management.

We have other staff in the agency, Matt Humberstone from the Office of Nuclear Regulatory Research, Steve Philpott, Jorge Hernandez Munoz, Duke Kennedy, and Amy Cubbage from the Office of Nuclear Reactor Regulation, and Matt Sumerov (phonetic) from the U.S. Department of Transportation, who is a partner with us in all matters regarding transportation of radioactive materials.

So, while you're hearing from a few today, as well as folks from the lab who were very involved with this effort, there is a lot of effort behind the scenes supporting the presentations that you'll hear about today, and I thank everybody who has been involved with us to date.

So, as Dr. Ballinger noted, ACRS views are very welcome to the staff. It will inform the work that we're doing, and we're looking forward to a very productive discussion. Unless the Committee chooses, we're not looking for a letter at this time, but of course, that's not my decision to make.

As Dr. Ballinger noted, that would be a decision by the Committee. So, but, you know, for now, we're looking forward to a good information presentation, and I'll turn it over to the next speaker. Thank you.

MEMBER REMPE: So --

CHAIRMAN BALLINGER: Jeff are you going to --

MEMBER REMPE: Before you start, I guess I have a question. I mean, you have the safety evaluation and you said well, we'll be informed by what ACRS says today. Would some of the questions we raise maybe, would they be used in an update to your safety evaluation or is it, is the water -- has the ship already sailed and it's too late?

MS. HELTON: No, it's not too late. We are still continuing to work on the safety evaluation. The one that we made public to support this meeting is a draft and that was really just to ensure that we have a good, full public discussion.

The draft that the ACRS has, has not yet been fully reviewed by management. I think there's a big disclaimer on there that our lawyers helped us write. So, we're continuing to finalize our review, and Bernie will get into the schedule and the next steps for the remainder of our efforts.

MEMBER REMPE: Yeah, we can find out if there happens to be some divine insights from the members that would be recognized and addressed, and maybe we could have a short meeting at full Committee to say yeah, we agreed and did something.

MS. HELTON: Absolutely.

MEMBER REMPE: Thank you.

CHAIRMAN BALLINGER: Let me get a little bit of clarity here. What the staff did was to review the document. I don't believe this document that we got is called the safety analysis, so it's not a safety analysis.

MEMBER REMPE: Well, no, a safety evaluation, but --

CHAIRMAN BALLINGER: It's not a safety -- it's a review.

MEMBER REMPE: It's an evaluation is --

CHAIRMAN BALLINGER: So --

MEMBER REMPE: -- what I've heard, right?

CHAIRMAN BALLINGER: So, that makes it a little bit different than the normal procedure that we have.

MS. HELTON: Right, we're not actually reviewing a transportation package design. We don't have the safety analysis in front of us to review. What we're going to present on today is our thoughts on the risk method and it is a little bit different. As you know, it's sort of akin to -- I think of it like a topical report sort of review, although we're not calling it that, but it's that sort of process where we're looking at the method.

And Bernie will talk about how the next step, you know, assuming that the NRC makes a favorable finding, of the method would be for an applicant for a transportation package design to use that method and apply it to their package and use it to demonstrate how they meet the requirements of 10 CFR Part 71, so I hope that helps.

CHAIRMAN BALLINGER: So, to add a little bit more clarity, so what you're inferring is that at a later time, there may be a document which we do formally review and you would require, would like a letter?

MS. HELTON: Yes, we'll be presenting about that today.

CHAIRMAN BALLINGER: Okay.

MEMBER REMPE: But once this evaluation, isn't that what it's called is an evaluation, is completed, would it be considered an approved approach? So, if we have a concern, we ought to make sure we get it down now instead of after somebody comes in that's an applicant and says well, we had the evaluation. It was approved or received a favorable outcome from the NRC. So, it's better to make sure that if we have a concern, to raise it now instead of later, right?

MS. HELTON: Yeah, I think we're open to any thoughts that you have today.

CHAIRMAN BALLINGER: Okay, Jeff, do you want to make a comment?

MR. WAKSMAN: Sure, so I definitely want to thank everyone for coming here today and I want to echo what Dr. Ballinger said up front about this being a lot broader than Pele. In fact, this is intended to be much broader than Pele.

The Pele reactor, as we have plans now, is not going to leave the Idaho National Laboratory site after it's been operated. The intention is to test the transportability just by driving it around the property.

But the purpose of Project Pele is not to just do a prototype. It's to have follow-ons, and so we are hoping that the DoD will purchase more reactors, which will probably be a different design, so we want this to be much broader than just the Pele design and its specifics.

And so, I think so far, we've had a really good dialogue and working relationship with the NRC team, with Bernie and all of his folks, and so with that, I'm going to turn it over to the person who understands this a lot better than me, Harold.

MR. BLEY: Ron, this is Dennis.

CHAIRMAN BALLINGER: Yeah?

MR. BLEY: Dennis Bley. From the staff, I'm a little interested in exactly how you see what you're doing now. To my knowledge, NMSS and NRC, with regards to transportation in the past, has regulated the integrity of transportation casks for spent fuel.

This, I believe, is the first time you've looked at transportation of an actual reactor, either before it's been operated or after it's been operated, and is that going to require a new rule or where do you see this going?

MR. WHITE: So, this is Bernie White, NRC staff. So, if you look at the transportation regulations in Part 71, they're fairly broad. They cover a wide variety of packages, and essentially none are specified by name. So, we have Type B packages and we have fissile material packages.

If we were to approve a transportable micro-reactor prior to shipment, it would likely be a Type A fissile package, which is different from a Type A package. After irradiation or after use, it would likely be a Type B fissile package and it would have to meet the requirements for a Type B fissile package or use an alternative approval pathway that I had mentioned previously in the October 3 ACRS meeting, which would include alternative testing conditions or exemptions.

The proposal here from PNNL is a, and from SCO is, I like to think of it as a roadmap. It's how to get from point A to point B, but you never know along the way when there's going to be a road closed or a detour and you've got to do something different, and so that's kind of how we see it. It's a method to get us to be able to develop an application for package approval for the Pele micro-reactor.

MR. BLEY: Okay, thanks, and I guess that means you think the regulations that exist for Type As and Type B packages are going to be able to cover this? We don't need new regulation?

MR. WHITE: This is Bernie White again, NRC staff. At this point, yes, and you know, part of the reason for that is in the conversations we've had with micro-reactor developers, so far none other than the Pele development of this methodology have indicated they need to use exemptions.

You know, staff is always balancing the act between what staff can do on its own and what is a policy issue for the Commission. You know, if we were to hear of eight or ten micro-reactor developers that need to use exemptions, you know, it might be best to not regulate the exemption. It might be best to do rulemaking. We're still evaluating that at this point.

MR. BLEY: Thanks very much.

MS. HELTON: Bernie, this is Shana Helton again. If I could just add, so, you know, these are all exactly the types of questions that we hope to answer today with the staff presentation.

Following, you know, Dr. Waksman from SCO will be talking, along with PNNL, about the risk methodology itself, and then our intent with the staff presentation is to get into the details of how we're looking at the method, how we see that fitting into our framework for this one time, for Project Pele, and then some of our considerations and next steps going forward. So, I do believe we'll have the chance later today to really get into these considerations.

Part 71, I just wanted to note, and Bernie will probably talk about this during his presentation, has been used for some different types of shipments that don't look like what you think about with your typical radioactive material spent fuel types of transportation.

We've done some sort of -- and there's provisions in the regulations that allow for the use of alternate criteria, and of course, exemptions are always a possibility for a one-time, unique situation. So, Bernie will get into all of that and the flexibilities that are in the Part 71 as it's written today. Thanks.

CHAIRMAN BALLINGER: Okay, we may be getting ahead of ourselves, but in the document itself, there's a statement. Given these observations and the fact that this is a first-of-a-kind endeavor, it is recommended, however, that a PRA standard for

TNPP transportation would greatly aid the NRC approval process, so that's from your document itself. Okay, who is the presenter?

MR. ADKINS: It's Harold Adkins --

CHAIRMAN BALLINGER: Ah, okay.

MR. ADKINS: -- from PNNL. First of all, I'd like to thank the Advisory Committee on Reactor Safeguards, the Nuclear Regulatory Commission --

CHAIRMAN BALLINGER: Can you get a little closer to the --

MR. ADKINS: Oh, you bet. Sorry about that. I figured I was loud enough.

CHAIRMAN BALLINGER: Or just pull the thing -- there you go.

MR. ADKINS: How's that? Terrific. Anyway, so Garill Coles and myself will be primarily providing the presentation, but I brought some support staff that range all the way from Army transport logistics experts to thermal hydraulic structural reactor physics experience and things of that nature, risk and decision making, and also consequence.

Anyway, so thank you for allowing us to present on the development and application of a risk-informed approach for highway shipment of a micro-reactor. Next slide, please?

The very first thing that we want to do, our objective here is to propose background information on a proposed risk-informed regulatory approach to the transportation of a transportable nuclear power plant, and we use that loosely because one of the things that we'll get into is, the one example that we make is where the reactor module is separated from the balance of the plant and sealed off and prepped for transport as a transportation package, and all of this is being developed in support of an NRC draft safety evaluation or a SAR submittal from the applicant.

We'll provide a brief description of the TNPP, the one we made an example of, which is Project Pele. We'll provide a description of the proposed risk-informed regulatory pathway that we're proposing for the TNPP transport.

We'll go through some development of risk evaluation guidelines, some description of quantitative risk assessment process using integrated assessment processes based on probabilistic risk assessment. That's the coupling to that, some methods, which include consideration of defense-in-depth, and also consideration of safety margin.

We'll also make some examples of results of applying the proposed PRA and risk evaluation guidelines to the TNPP, for an example, a description of the approach to the results of the sensitivity studies and then certain analyses that we performed only as an example of pathway and process, because that would still be the burden of the applicant, and then provide some insights gained for implementing and demonstrating our proposed approach. Next slide, please?

So, first out of the gate, we talked about what a TNPP is. Many advanced reactor vendors are now proposing and developing TNPPs to make higher density energy readily available for -- specifically, one of the major drivers and funders of this activity was DoD's Strategic Capabilities Office.

Jeff Waksman provided us the capability of developing this on behalf of SCO, and it's for the Department of Defense domestic infrastructure resilience to electric grid attack.

It's also being developed to enable rapid response for humanitarian aid and disaster relief operations, to be able to expedite that, again with high-energy density, and then also to provide clean carbon energy in a variety of austere conditions or off-grid locations.

The one convention that I do want to make clear here is the TNPP convention would be a factory-produced, fueled, acceptance tested, deployed and sealed units that are prepared for transport as a transportation package. They would be utilized and then retrieved for refueling or reapplication, meaning that our main focus and the critical portion of this would be the post-transport shipment, meaning the spent fuel is within it, and the considerations associated with that. Next slide, please.

To make an example, again of Project Pele, that we used to do the development. It's a one to five megawatt electric minimum of three years' operating time for full power. Obviously, the lifetime would be longer than that if it was utilized at anything other than full power. It's a high-temperature gas reactor using high-assay, low-enriched uranium, uranium oxycarbide tristructural isotropic fuel.

In the Pele convention, it's separated into four modules, one of which is the reactor module or heat generation module, then you have an intermediate heat exchanger module, a control module, and a power conversion module. However, a bulk majority of the radionuclide inventory would reside in the heat generation module, the reactor module, and the balance is anticipated in the intermediate heat exchanged module.

Each one of these modules in the Pele convention is housed within a CONEX box to look like simple cargo, and a CONEX box is like a shipping container that you would see on a shipping port or on a cargo ship, and then the image to the right basically that you see is a caricature or a rendering of a deployment for Army application. Next slide, please?

So, U.S. transportation regulatory requirements contained in 10 CFR 71, yeah, 10 CFR 71, sorry, primarily focus on the definition of thick-wall pressure vessels that are intended for spent nuclear fuel transport. A TNPP with irradiated fuel, like we talked about the convention that we're discussing and focusing on, prepared as a package for transport could be challenged to meet the entire suite of codified regulatory performance requirements in 10 CFR 71.

The one thing I want to be clear on though is it's fully anticipated that TNPP would be able to meet or at least be deterministically shown to meet normal conditions of transport because that would be like a general commerce state where you can't have any particular incidents or you want to mitigate those incidents.

However, it may be a bit challenging to demonstrate that the level of robustness of current proposed TNPP technology can fully meet these requirements, such as dose rate requirements and containment success criteria when exposed to a postulated hypothetical accident condition that's charted out in 10 CFR 71.73, and what I mean by that is the sequential 30-foot drop. It's the worst case scenario, a crush, puncture-free drop, a 30-minute engulfing hydrocarbon fire, and then water immersion tests.

One of the things that we're focusing on too is leveraging compensatory measures and defense-in-depth approaches along with philosophies to reestablish the equivalent safety that would be provided by the codified regulatory requirements. We're also absolutely intending on leveraging consideration of the TRISO compact fuel sleeve core, all of these retention and protection boundaries to provide equivalent safety. Next slide, please?

If a fissile material or Type B package like we discussed previously can't meet the postulated hypothetical accident requirements in 10 CFR 71.73, there's a couple of options that the NRC considers. First of all, there's a 10 CFR 71.41(c), which it's detailed in that, as an alternative environmental and test condition state.

This has been applied to two separate packages in the past, ones I'm just making example of, which is the 10-160B and the 8-120B. In those particular cases, the one workaround that had to be navigated was the low temperature transport application, so they took an exception to the transporting at the lowest possible temperature.

The next one is this special packaging authorization that's been applied to the West Valley Melter Package, and that one's slated out in 10 CFR 71.41(d). That only allows for a single-time shipment, so from source to destination, and then that SPA is expired.

The one consideration that we're taking into account probably that would be the most fruitful is the 10 CFR 71.12 exemption that's been applied to the Trojan Reactor Vessel, and in that particular case, the reactor vessel was transported up the Columbia River to the Hanford Site, and then transported to its destination, and compensatory actions were taken into account because it was too large to actually perform the physical testing or taking a look at that.

Our preferred approach initial pathway that we identified was the exemption process, again, that allows compensatory actions to protect the basis for the exemption if acceptable risk is demonstrated. We can apply it to more than one shipment, first of all.

That's one of the major drivers, and then the other thing is there's flexibility in deviated from the deterministic requirements, especially HAC requirements, to alternative environment and test conditions like I talked about where only one particular item is a weakness like the low-temperature application. Next slide.

MEMBER HALNON: Harold, this is Greg. Just a real quick question.

MR. ADKINS: Yeah.

MEMBER HALNON: Is your approach very specific to the Pele reactor or are you broadening it out to include potentially bounding some other types? What about TRISO fuel and other things?

MR. ADKINS: Excellent question. For the time being, it's not fixated on Pele, but the one requirement that we've all agreed, without during further work, it will likely be tied to TRISO fuel.

MEMBER HALNON: Okay, so it's TRISO fuels centric rather than --

MR. ADKINS: Exactly, exactly.

MEMBER HALNON: Thanks.

MR. ADKINS: That doesn't mitigate us from, you know, moving further and considering other things that might be tied to an alternative reactor design.

MEMBER HALNON: Okay, because I know that there's some molten salt reactors out there that --

MR. ADKINS: Right.

MEMBER HALNON: -- are looking at a similar aspect, only different fuel.

MR. ADKINS: Okay, or sodium-cooled. Thank you. Good question. Thank you. Thank you. So, quantitative risk analysis approaches such as PRA have been applied and used in risk-informed regulatory pathways for licensing particular systems, especially in reactors, since the 1970s nuclear reactors.

PRA has been applied ever since WASH-1400 and used since the 2000s for licensing. PRA has also been applied to dry cask storage systems, as well as transportation systems, and I've identified a couple of NUREGs that highlight a lot of that.

One of the reasons that we're focusing on this and proposing to the NRC is to provide an aid for developing the near-term pathway to drive advanced, factory-produced TNPP development and deployment. The other thing too is, you know, going back to the comment that I made about the codified regulatory requirements almost exclusively revolving around thick-wall pressure vessels.

When you take into consideration like a spent fuel cask, and then also as the TNPPs go through a refinement process and robustness where those two points come together in, you know, consideration of regs and things of that nature, it provides buffer time for strategic regulatory consideration and the possibility of rulemaking to more so accommodate advanced, transportable, and micro-reactor conventions. I'm going to hand the rest of the presentation over to my colleague, Garill Coles, to speak to the risk-centric items.

MR. COLES: Okay, Harold, I'll take it from slide eight. Yeah, so we contend that a demonstration of acceptable risk, if the exemption process is used, would require a quantitative risk assessment given possible complexities and uncertainties about the package performance and the potential risk to the public, and in fact, that this would be a first-of-a-kind endeavor.

Moreover, unlike the Trojan Reactor Vessel example, it is unlikely that all accident scenarios would be screened based on likelihood. PRA provides a rigorous quantitative approach.

And concerning risk evaluation guidelines, assessment using PRA worked best and was supported by guidelines about acceptable use, acceptable risk, because they provide a key basis for risk-informed decision making. However, regulatory risk evaluation guidelines using PRA do not exist for transportation packages like they do for nuclear power plants.

That said, risk-informed decision making guidance using PRA and other risk assessment approaches is proposed for nuclear material and waste applications in the 2008 NRC report titled Risk-Informed Decision Making for Nuclear Material and Waste Applications Rev. 1, and we're going to refer to this report, and there are times in this presentation I'll shorthand it by calling it the 2008 RIDM report.

The guidance in that report includes proposed quantitative health guidelines developed from the 1986 NRC Safety Policy Statement. However, challenges remain in implementing the guidance, and the approach has not been endorsed for use by NRC for transportation. So, this slide --

MEMBER ROBERTS: Garill?

MR. COLES: Yes?

MEMBER ROBERTS: This is Tom Roberts. I have one question about the 2008 RIDM report. It might be a question for staff, but I'm going to ask you first. It doesn't talk about the qualitative safety goals from the 1986 statement.

One of the qualitative goals addresses societal risk and, you know, a wise person once explained to me that one of the biggest differences between transportation and other regulations is because transportation can go through population areas without any real controls over population.

That's distinct from a nuclear reactor plant that has guidelines like population density guidelines and, you know, LPZs and maybe EABs and that type of thing, which don't apply here. So, this is kind of a battery condition for reactor risk analyses that don't apply to transportation.

So, I was wondering what your thoughts were on societal risk, whether you thought about the need for a societal risk goal in your quantitative assessments, and if not, how that's considered in kind of the overall overhead with the analysis you're doing?

MR. COLES: Well, as you say, right, there are no guidance using PRA. There's no -- and we didn't try to rethink. That's almost like rulemaking or something. So, we used -- and I'll explain this in the next slides, right?

I basically used the information at hand, and most of the information at hand is for facilities, as you say, and that is different, and we'll explain how it's different and what we did about that.

MEMBER ROBERTS: Okay, yeah, I'll be interested in hearing that. I noticed the transportation risk analysis that you cited had an awful lot of tables of person-rem, and so they were looking not at just the individual risk, but the total population risk, though I didn't really see a conclusion that was drawn, so that's probably consistent with the Commission not establishing a quantitative goal back 1986 because it's --

MR. COLES: Right.

MEMBER ROBERTS: -- not obvious what that goal would be, but certainly there was consideration of overall populations in that report. And the guidance, yeah, in your report are these guidelines on the slide you're about to present, so I just wanted to get your perspective on -- and maybe this is a question for Bernie when his turn comes up, but if staff thought about that in terms of how you would look at the societal risk considering when you're looking at a risk analysis that's focused on the risk to the individual.

MR. COLES: Yeah, bring up the question again if we don't answer. So, this slide does show the quantitative health guidelines proposed in the RIDM report. Of course, the premise of the safety goal policy is that risks to people from nuclear power plants should be very small compared to the sum of other accident risks. That's the one-tenth of one percent.

The safety goal doesn't actually specifically address workers, but the RIDM report proposes that the worker risks be small compared to others, but not as small as for the public who are not trained or equipped in radiation protection.

So, this table is just a summary, and I've organized the quantitative health guidelines into three levels of harm, acute fatality, latent cancer fatality, and cancer illness. The table then shows the different risk criteria thresholds proposed for each level of harm, both to the public and the workers.

For example, the point at which acute fatality becomes unacceptable is when it is greater than five E to the minus seven fatalities per year, and, of course, the RIDM report itself goes into great detail about the basis for this criteria. Next slide, Bernie?

This slide presents our basis for using surrogate measures in place of the proposed QHGs, the qualitative health guidelines. In a PRA of a nuclear power plant, there are three levels of analysis.

Level one is determination of core damage frequency, we call that CDF, and large early release, LERF, or we call that LERF. Level two is quantification of the release of radiological material, and level three is determination of health effects from the releases.

However, nuclear power plant PRAs, which are quite mature, and use risk-informed applications for the current fleet, and not currently taken to level three, but rather use the surrogate of CDF and LERF to support risk-informed applications because those values are more feasible to determine. The basis for accepting those surrogate measures is spelled out in NRC Reg Guide 1.200.

So, in a like vein, PNNL proposes the use of surrogates in place of the 2008 RIDM report QHGs by formulating limits in terms of radiological dose and likelihood pairs. This provides advantages such as a reduction in calculational burden by eliminating determination of health effects, and as you pointed out, Tom, you know, it's worth remembering that along the transportation route, the population is in constant flux.

The second advantage is that the dose limits can be compared to other federal and international dose limits used in related contexts for a perspective like the worker dose limits. Thirdly, determining likelihood and consequences separately provides a greater level of information for decision making rather than combining them into an accepted value.

So, PNNL examined the use of dose consequence-likelihood pairs that are used to evaluate risk in other applications. NEI, the Nuclear Energy Institute, NEI, 18-04 guidance uses this concept for risk-informed licensing of advanced non-light water NPPs, nuclear power plants, which have been endorsed by the NRC, and Department of Energy, DOE Standard

3009 guidance uses this concept in their semi-quantitative risk ranking approach in support of nuclear safety of non-reactor nuclear facilities.

Guidance in these two NUREGs and 10 CFR Part 70 are used in integrated safety analysis for determining performance requirements for nuclear fuel cycle facilities, and lastly, the Q system in Appendix 1 of the International Atomic Energy Agency's specific safety guide, SSG-26, uses a reference dose to determine a quantity limit of radionuclides in a Type A package. So, for example, this slide shows hypothetical risk evaluation guidelines for radiation dose that were generated based on guidance for performance integrated safety analysis.

The table was developed by putting together the radiation dose levels defined in 10 CFR Part 70 for high and intermediate consequences for the work and individual members of the public, and frequency definitions for unlikely and highly unlikely events at 1-E minus five and 1-E minus six per year.

The table is a little bit hard to interpret if this is the first time you've seen it, but you can see that use of discrete frequency and radiation dose pairs in this way creates intervals between the defining points.

So, I'll show you in the next slide how this looks graphically, but for the moment if we look at that middle row, it indicates that if the frequency is less than 1-E minus four per year and greater than 1-E minus five per year, and the radiation dose to a member of the public is greater than or equal to five rem and less than 25 rem, then the risk is acceptable. And applying the limit in this way creates this stairstep shape when you plot it on a graph, so I'm going to show you in the next slide --

MEMBER REMPE: Before you go to the next slide, I just want to make sure I understand what you've done in how you estimated the dose. Am I to assume the exposure is a 50-year exposure for the person, and then Tom mentioned what's the zone, so how far was that person? If it's a worker, I assume it's closer than the public. Could you talk a little bit about --

MR. COLES: We actually have a slide later where we talk explicitly about how we calculate the consequences to the worker and the public. There's actually a couple slides.

MEMBER REMPE: And the justification for making those assumptions, okay?

MR. COLES: Yeah, we --

MEMBER REMPE: That's great. Thank you.

MR. COLES: Next slide, Bernie? So, this graphic form is a little easier to absorb. This slide shows the same hypothetical risk evaluation guidelines as the last slide for the public. You can see that the criteria forms this shape, stairstep shape when plotted in graph form.

So, if the calculated risk of interest when plotted on the chart falls in the blue shaded region, then the risk is determined to be in the acceptable range, and if the risk falls above the blue line, then the risk is considered to be in the unacceptable range.

These same kinds of criteria are used in the document of safety analysis for DOE non-reactor nuclear facilities to identify when nuclear controls are needed. In a like vein, the same or similar criteria is used in NEI 18-04 to support risk-informed licensing of advanced non-light water NPPs, which we show in the next slide.

So, this is a slide directly from NEI 18-04. It shows the risk guidance in short form referred to as the frequency consequence targets. You can see it's more complex than the previous chart, but the concept is the same.

And there are different ways this chart is used in assessing individual risk, but for the sake of this example, license basis events whose consequence and likelihood define a point that falls above the blue line are in the acceptable region again and events whose consequence and likelihood define a point that falls below the blue line are in the acceptable range.

There are further considerations such as the impact of modeling uncertainty that need to be addressed, but in general, use of the criteria in this way is a way to essentially control risk below the blue line. NRC has endorsed this approach. Go ahead.

MEMBER BIER: Okay, I have a couple of questions, and it's not really about any one of these graphs, but about the whole philosophy of them, and I realize these are pretty commonly used. For simplicity, why don't we go back to the previous slide just because it's easier to read? Great.

So, for a given risk analysis like what you did for Pele, you would generate not a point, but a like complementary cumulative or something that would be judged against this or --

MR. COLES: Right, we'll describe it in more detail, but what we do is define bounding representative accidents, this is kind of a smaller set of accidents, and then we plot those on --

MEMBER BIER: Okay.

MR. COLES: -- the graph.

MEMBER BIER: Because like I said, I realize this is a pretty common approach, but I've never been completely comfortable with it, so, I mean, two issues. One is just that the black and white division between acceptable and unacceptable seems maybe a little harsh or whatever.

But more to the point, let's say we have plotted the risks and, you know, there is one point, one scenario that falls just slightly above the blue region, but all of the others are way down below the blue dividing line, and it seems to me like that does not make that design that was analyzed unacceptable. Really, the higher risk in one area is more than outweighed by very, very low risk comparisons in other areas, so I'd just be curious to have your thoughts about that or comments.

MR. COLES: Yeah, that's a really good setup for later in the presentation. We're going to show you exactly that example and, you know, just as a preamble to that, you know, the concept of certainty has to understood --

MEMBER BIER: Yeah.

MR. COLES: -- right? That's part of it, and then because this is an exemption process, you know, if you are right above the line, you know, there's a way in which we can use controls.

MEMBER BIER: Okay.

MR. COLES: Yeah.

MEMBER BIER: Maybe I'll wait and come back to this then later --

MR. COLES: Yeah.

MEMBER BIER: -- when you get to those slides.

MR. COLES: Good question.

MEMBER ROBERTS: This is Tom Roberts again. I have a question related. If you could go back again to the previous page? The NEI standard for the LMP-based approach, which is risk assessment, has a requirement that serves for cliff edge effects.

MR. COLES: Yeah.

MEMBER ROBERTS: So, you're required to go beyond the five times ten to the minus second frequency to see if there is something just off the range of probability that would have a huge change in result.

I didn't see any discussion of that in

this report, and you'll get to it, but criticality excursion seems like it would tend to fall in that category because it's definitely in the neighborhood of five times ten to the minus second, and you chose to not look at the consequence because it was straight up the --

(Simultaneous speaking.)

MR. COLES: We will --

MEMBER ROBERTS: So, I wonder what the thought is on cliff edging.

MR. COLES: Yeah, we actually mirror your comment in a couple more slides.

MEMBER ROBERTS: And we'll discuss --

MR. BLEY: Hey, if everybody could stay on the microphones, it would help those of us outside the --

MEMBER ROBERTS: Sorry about that, my fault, my fault.

MR. COLES: So, one thing I should mention, the NRC has endorsed this 18-04 approach in the next slide that we're looking at, but they do provide the caveat this figure does not represent risk acceptance criteria or actual regulatory limits. Nonetheless, the figure does provide a way to help demonstrate that the risk is acceptably low, but we are going to come back to your comments in a slide or two. Next slide?

So, to develop our proposed risk evaluation guidelines, right, we first synthesize a set of limits using the likelihood-consequence pairs from or based on the applications we investigated for facilities as we discuss.

There are some examples of using a risk-informed approach for the transport of a package, we discussed earlier, but risk evaluation criteria were not developed in these cases. Facilities are stationary, of course, and not subject to transportation hazards. On the other hand, the TNPP will not be operating during transport.

So, given there are no risk-informed guidance for transportation PRA, we drew from facility experience to develop our proposed risk evaluation guidelines, and also we propose that transportation-specific hazards can be addressed in the PRA.

So, then we, to develop these guidelines, then we converted the likelihood and radiological dose consequence limits to health effects using conversion factors published by DOE to convert radiation dose to mortality and morbidity. The source of these conversion factors precisely is the bottom of that slide.

Then as a third step, we readjusted some of the likelihood-consequence pairs to ensure that each limit was less than or approximately equal to the qualitative health guidelines that were proposed in the NRC RIDM report, acute fatalities being the most limiting case. We believe this process that we use resulted in a conservative set of likelihood-consequence pair limits. Next slide.

Okay, so this slide shows the proposed risk evaluation guidelines. The blue figure on the left is for a member of the public at a defined distance from the accident assumed to be maximally exposed. We're going to go into more detail in several slides forward.

The orange figure on the right is for the worker who is generally assumed to be closer than a member of a public, typically one meter. The term workers indicate individuals who are part of the radiation protection program and could receive an occupational dose.

The likelihood is presented in accidents per year. The radiation dose levels are provided in total effective dose equivalent, which is the integrated committed dose to all organs, which accounts for direct exposure as well as the 50-year committed dose.

We implemented our demonstration PRA based on a single shipment. To compare the risk of multiple shipments of the same package against these guidelines, the accident frequency would need to be increased proportionately.

In the proposed risk evaluation guidelines, if the accident frequency is 5E to the minus seven per year, then the risk of the accident scenario is generally acceptable. However, as Tom pointed out, if the accident frequency is less than the 5E to the minus seven per year, it should be evaluated to confirm there are no cliff edge effects.

MEMBER REMPE: So, again, I'm trying to be patient here, but are you still planning to tell me at some point what you assume for the exposure duration for the worker and the public, and specific factors?

MR. COLES: I am.

MEMBER REMPE: Is that coming up in another slide? I was looking at the rest of the slides and I just can't figure out where it's coming, but you --

MR. COLES: Well --

MEMBER REMPE: -- you won't forget.

MR. COLES: I won't, and specific, if you want to look ahead, it is in step six of the --

MEMBER REMPE: Okay.

MR. COLES: So, slide 24 or something like that. It's a bit ahead.

MEMBER REMPE: Okay, that's fine. I'm sorry. I just didn't want to lose it because it looked like you were getting to another concept.

MR. COLES: So, this slide shows our process for using PRA. The primary difference -- I know Dennis is on the line. The primary difference between our process and a conventional PRA used for reactors, for example, is that we use the accident development process to select and define the bounding representative accidents, which I'll describe in detail a little later, and then we determine the likelihood-consequence for those bounding representative accidents.

And I recognize this figure is hard to read. I just present it to give you a sense of the overall process. I'm going to just name the steps and then we're going to talk about each one in detail. It's a compilation of the TNPP design and shipment route information.

There's identification of the package

safety functions, and there's identification and development of accidents, selection of the bounding representative accidents, and then we develop the likelihood and we develop the consequence for each PRA, and then we compare the results to the risk evaluation guidelines, and we assess sensitivities and uncertainty, and then we assess defense-in-depth and safety margin. Next slide. This slide shows step one. This is --

MEMBER MARCH-LEUBA: Excuse me, this is Jose. Can you go back to the -- it's something that you said about the one reactor versus 100 reactors. If I -- if there is a centralized factory somewhere in, say, Ohio, that produces all of these reactors and ships them all over the world, on a legally accessed road to this facility, all 100 of those go by my home a year. How do we factor that on the acceptance criteria? I mean, do we reduce the frequency by the expected number of reactors that would travel near my house?

MR. COLES: Well, that's a really good question and there are some complexities to applying the guidance that would need to be sorted out if we started talking about multiple reactors and multiple shipments per year and how would that be done in practice. It's a very good question. How would you, like, track the risk if a reactor is moved a number of times a year? Those questions, although we discuss it a lot internally, we haven't sorted those out.

MEMBER MARCH-LEUBA: Yeah, the problem conceptually is that I can ask good questions. You are tasked with providing the answers for them on your documents. I mean, I'm the lucky one.

MR. ADKINS: There you go. One of the comments we'd make to that too is when they're deployed, obviously they would be green or non-utilized, right, and so there's a lot of things to take into consideration, especially when you're retrieving them to recycle or disassemble, dismantle.

MEMBER MARCH-LEUBA: Especially the used ones, yes.

MR. ADKINS: Yeah, exactly, exactly, and so we were looking at that as being partially beyond the scope of what we are trying to show as the pathway and process, and quite literally, this would tie back to the vendor and their responsibility to submit something to the NRC that would prove without a doubt that they were maintaining reasonable assurance of adequate safety through their process and their concept definition, right, so I guess we left that to the reader.

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: Can you talk closer to the microphone? We can't hear you.

CHAIRMAN BALLINGER: Yeah, what happens is when you're closer to the microphone, everybody hears you. When you back up a little bit, nobody hear you. But how is that question different than shipping spent nuclear fuel?

PARTICIPANT: Exactly.

MR. COLES: It's not --

MEMBER PETTI: I mean, that could be handled with the manufacturing license --

PARTICIPANT: Exactly.

MEMBER PETTI: -- right? I mean, I could obviously --

PARTICIPANT: Yeah, exactly, yeah.

MEMBER PETTI: Let's say I'm taking the shipment back to where it was manufactured.

PARTICIPANT: Sure.

MEMBER PETTI: Then it could be encompassed in their safety analysis --

PARTICIPANT: And --

MEMBER PETTI: -- as sort of, you know, it's the equivalent of co-located hazard, right, where there's a chemical plant or something.

PARTICIPANT: Right.

MEMBER REMPE: But is that coordination going on at NRC? I mean, we're trying to develop stuff for the manufacturing license at the same time as the shipping, and so that's a good thing that NRC ought to be thinking about.

MR. WHITE: Bernie White, NRC staff. It absolutely is something we're thinking about. And so, I think you brought up the fundamental difference between reactors and transportation, although you haven't necessarily explicitly stated it, in the fact that spent fuel shipment, as was discussed, you know, those packages meet the regulations in 10 CFR Part 71. There's containment criteria, which I have a big slide on I'll probably skip now that I'm talking about it, and there's dose rate criteria.

The risk assessments that we've done in the past have shown if you meet those, and when I say meet those, so under normal conditions of transport, there's a release of we would say less than ten to the minus six to A2 per hour, so a millionth of an A2, and A2 is the maximum quantity authorized in a Type A package, and for accident conditions, it's an A2.

So, you limit the dose to an individual by how much material is released to no more than five rem in an accident at most, and you've limited the direct dose to an individual because the dose rate is limited in shipment. You know, it's ten MR per hour from the walls of a vehicle.

You know, I'm talking a spent fuel package, so it's probably a train or a truck. It's an exclusive use shipment, and so it's, you know ten MR per hour two meters from there or one R per hour in an accident.

You know, one R per hour, you'd have to be there a pretty long time to get a significant dose that would cause, you know, significant injury. Chances are first responders would show up and cordon off the area like they're supposed to before that.

And so, you know, when we do risk assessment in transportation, we don't know where the packages are going to go. We don't -- I mean, because it could be anything from a spent fuel package to a radiography camera. Radiography cameras are shipped all over the world, all of the U.S. every single day, and they have the same radiation requirements as spent fuel packages do.

The -- and I'm trying to be curt here a little bit, but when you look at how a transportable micro-reactor is going to be shipped -- you know, you brought up what up if it's, you know, 100 reactors come out of a factory and ship worldwide? Well, therein lies the problem.

To ship worldwide, it's just not the NRC and the DOT that have to accept the approval of that package. It's also foreign competent authorities, and therein lies kind of the issue that we in the staff are struggling with.

We don't know what -- we don't have analysis for transportable micro-reactors and how they fair in a 30-foot drop, for example. What do they release? We haven't had those discussions yet, but whatever NRC approves would have to be accepted by a foreign competent authority for import shipment into that country, which is different from a reactor.

MEMBER MARCH-LEUBA: Yeah, my comment was not as it cross from the border into Canada. It's as it comes out of the facility and drives to my home in Ohio, which there is only one road to the facility and all of them go through there.

Let me give you a cheap and dirty solution that I would like you to consider. My claim is that transporting one reactor through my home at the exit to the factor has the same probability of failure, the same risk as transporting 100, exactly the same, and the reason is if you're shipping the reactor by my house and you have an accident, and you cause a five rem to somebody, you are not going to ship the other 99 after that. You're going to stop shipping and fix it.

So, the fact that you will -- you have plans to ship 99 more, those were plans. It's not going to happen. So, the fact that you have plans to ship 99 does not increase the probability of an accident happening.

MEMBER REMPE: And furthermore, you'd nuke the house, but you couldn't sell the property.

(Laughter.)

MEMBER MARCH-LEUBA: Yeah, yeah, and that brings the issue that we've always held with multiple reactors in a single site. When you do the PRA, we tend to do the PRA for a single unit because it's easier, and the issue with multiple reactors at a single site is that you could have common cause. You lose power, offsite power and you don't lose one unit. You lose three units.

So, when we move this concept to the transportation, it would be nice if we could require that you only transport one reactor at a time. Don't load a train with 12 because if you do load a train with 12 reactors and you have an accident, then you have 12 times the dose, but if you ship them one at a time, the moment you have an accident, you don't ship anymore. Anyway, that's my five cents, over and out.

PARTICIPANT: Thank you.

MEMBER REMPE: Before you finish talking, Bernie, could you -- you were talking about so many MR per hour and the rem that has to be released, which is really curies coming out, and someone's assumed a certain location and an exposure time. What do you guys assume on that?

MR. WHITE: You mean for Pele or for actual --

MEMBER REMPE: Just what you're doing, because I assume it's the same. I mean, what do you do when you're --

MR. WHITE: Right.

MEMBER REMPE: -- releasing a certain amount of --

(Simultaneous speaking.)

MR. WHITE: So, we tend to talk in A2s, and the reason we do that is because we don't know what any particular package is going to carry when we set up the regulatory requirements. For example, cobalt has an A2 value of something like 11 curies. Plutonium's on the order of 20 millicuries, and so they're different, and the idea is they would give you the same dose in the event of an accident.

MEMBER REMPE: You must be assuming a person is at a certain location for a certain --

MR. WHITE: Right, and that's --

MEMBER REMPE: -- for a certain amount of time --

MR. WHITE: And that's all baked --

(Simultaneous speaking.)

MR. WHITE: Right, and that's all baked into the Q system.

MEMBER REMPE: The Q system.

MR. WHITE: The Q --

MEMBER REMPE: Two regular reactors --

(Simultaneous speaking.)

MR. WHITE: Right.

MEMBER REMPE: Yeah, okay.

MR. WHITE: The key system was developed by IAEA for, particularly for transport of radioactive material. It looks at five different pathways. I'm going from memory here. I have a slide later. We both have slides on this.

MEMBER REMPE: And you'll give me --

MR. WHITE: Yeah, yeah.

MEMBER REMPE: Because I've looked ahead. I don't see it, distance, exposure time, and --

MR. WHITE: Right.

MEMBER REMPE: -- I'm curious because again, people could be moved off.

MR. WHITE: Right, and so we didn't bake that into our review. What we said is PNNL will presume 25 meters from an accident, and the reason they presume that is because of first responders. However, you could have an accident that happens before a first responder gets there, which is normally the case.

However, there could be mitigating compensatory measures such as rolling road closures. You know, if you don't allow vehicles within 25 meters of that, the closest person could be within 25 meters depending upon where houses and things sit off the roadways. That would have to be looked into, you know.

MEMBER REMPE: So, it's a sophisticated analysis --

MR. WHITE: Which is fairly route-specific.

MEMBER REMPE: Okay, and again, for a

worker, they're assuming that they would put on some PPE within a day or something like that?

MR. WHITE: So, the workers would likely be, if there are workers, the truck driver and escorting individuals. First responders are not typically considered workers. They're considered, you know, members of the public. They would typically wear PPE for a Type B fissile package in an accident. That's what the emergency response guidebook says for that type of response.

But what you'll hear in our presentation, in the staff's presentation is that PNNL said some really good things and we like what they said. However, the details are what's important. How close can a person actually be in the event of an accident? We don't know that from this.

MEMBER REMPE: Okay.

MR. WHITE: We may know that when we get the application in and we see compensatory measures that say you have escort vehicles. You know, you don't allow anybody within ten meters or 20 meters, 50 meters. And that may be needed to meet the normal conditions of transport dose rate. We haven't evaluated that yet.

We don't even know what these package

designs look like, so we're trying to approve, you know, a methodology at a high level where really the details is what we're going to get over the next few years. And as the old saying goes, and I have it on the presentation, the devil's in the details.

MEMBER REMPE: Yeah.

MR. WHITE: You don't know how that's going to shake out, you know, so we're trying to look at it from, I'd say, the 50,000-foot level. Can it get us where we need to go? Yeah, will it? Maybe, it depends.

MEMBER REMPE: This helps. Thank you.

MR. WHITE: Okay.

MEMBER REMPE: Go ahead.

CHAIRMAN BALLINGER: You do have a data point, naval reactors.

MR. WHITE: We do have a data point. However, we're not privy to that data because naval reactors ships under its own authority and they don't share that with us, and naval reactor packages meet Part 71 in their entirety.

CHAIRMAN BALLINGER: They do.

MR. WHITE: They do, absolutely.

CHAIRMAN BALLINGER: They have compensatory measures that they apply.

MR. WHITE: They do --

CHAIRMAN BALLINGER: Yeah.

MR. WHITE: -- but they're not because of the package approval.

CHAIRMAN BALLINGER: Ah.

MR. WHITE: Okay? The package approval meets Part 71 in its entirety, so they're not needed for our approval.

MR. COLES: So, Joy, just to go, I'll just mention though in our demonstration PRA, we assume that the worker is one meter, and that's consistent with the methodology and the IAEA guidance that we use.

And the public, we do recognize that there are some uncertainties, as was mentioned, about where the public may be located, but we use the distance, the standoff distance required by the Department of Transportation when you're moving high-level radioactive material, up to 25 meters, but we do a number of sensitivity studies, right, in the demonstration.

So, one of the things that's important, and I think you kind of alluded to it a number of times, is that the distance away from the point of the release is a key parameter, right? So, we've done sensitivity studies on that parameter. For this demonstration, I'm not saying what happened in the other case, but for this demonstration, that distance didn't make a big difference.

So, I'll pick up where we left off. I think Bernie was at that one. I think we talked about step one. Step two is identification of package safety functions. So, as you'd expect for a package, it includes providing containment of radiological materials, providing radiation shielding, maintaining criticality-safe configuration.

Regarding the fourth bullet there under step two, maintaining passive transfer of decay heat during transportation, this wasn't considered because, again, this is isn't a package. This is a reactor, and it wasn't initially clear whether or not this could be a safety function. It turns out for this demonstration design, loss of passive heat transfer is not a safety function, and so if you lost it, you wouldn't get an accident.

MEMBER REMPE: I have a question about this, too. In Part 53, one of the things that I like is that the staff did the critical safety functions. They had, you know, we're the nuclear regulatory agency, we're going to have the top level line B, contain radiation. And then they had lower level ones that challenge radiation containment.

In your case, radiation shielding and contain radiation, to me, are the top level ones. And then there's a bunch of other things that could challenge that. And, yeah, okay, you said, well, we considered passive cooling but for this particular design it wasn't important.

Since we're kind of looking at a broader approach, and not just particularly on this design, why not touch some other things that ought to be considered like control chemical reactions? As Member Halnon mentioned, you might have sodium, you might have molten salt. And I think that it might be good to broaden things a bit.

MR. COLES: Right. That's exactly why we do this step; right? The point of this step is to understand what the safety functions are. Because this is going to inform, then, our identification and development of accident scenarios. That's the only --

MEMBER REMPE: They don't pester the analysis, I know. I saw that in the document. What I didn't see was consider other challenges that should, should be, you know, thought about, even if you can dismiss them for this particular design.

MR. COLES: Well, that, that --

MEMBER REMPE: Although there's beryllium in there, there's tungsten in there, there's graphite in there. I didn't see that. But, of course, this is one document. I'm sure there's other documents I haven't seen. But I just thought it ought to be mentioned.

If staff is doing an evaluation of, a high-level evaluation of the methodology, I think it ought to be mentioned.

MR. WHITE: So, Bernie White, NRC staff.

So, from our typical parlance we fact test three safety functions: containment, radiation dose, and criticality safety.

How you get there is a lower level function.

For a typical package we look at a 30-foot drop, puncture test, fire test, and immersion test. While a lot of that seems mainly structural and thermal, we do look at packaging components. We look at the contents, how the packaging components interact with one another from a materials perspective. We look at the contents, how it interacts with itself for materials, you know, for material. And how it interacts with the package.

You know, we have package approved for uranyl nitrate. We would look at that. How, what facet was it contained in, the liquid, how does it interact, what material aspects could degrade the package such that when it's shipped, if it were in an accident would it maintain those three safety functions of containment, radiation shield criticality, safety.

So, we would look, the staff would look at that as part of the package application.

MEMBER REMPE: Yeah. Just it's always good to have it in writing. And I didn't see it in writing. And that's what I've been asked to look at to prepare for this meeting.

MR. COLES: Well, let's go to the next slide. And there might be an answer to your question partly addressed in this slide.

So, this slide shows steps, which is the identification, development of accidents. We use hazards analysis to perform the step because it is, because it is a comprehensive way to investigate what can go wrong.

So, that's the whole purpose of doing the hazards analysis: we want to understand, like you said, the samples you used were very good, what can go wrong?

And so, we start with the, you know, hazard I.D. checklist. We, we -- given that the -- Did you want to say something?

PARTICIPANT: No.

MR. COLES: Thank you. Given that the accident scenarios are not complex, though, like in a reactor, fault trees and event trees that are typical here for reactors weren't used because of the, the absence of active and passive systems redundancy.

Hazardous conditions were defined as conditions leading to the release of radioactive material or degraded shielding.

So, what you'll find as you go further, we, on the accidents we defined has nothing to do with that collision on the highway. It has nothing to do with transfer. It has to do with human error or mechanical failure or isolation devices, for example.

Worksheets were completed for possible hazard categories. Includes fire, explosion, kinetic energy potential, and loss of containment events, direct radiological exposure events, criticality events, manmade external events, and natural phenomena.

Highway scenarios include events such as collisions with vehicles or objects, collisions and subsequent fire, non-collisions such as rollovers and jack-knives, non-crash events involving externally initiated fire. Non-highway scenarios include events such as operator error, mechanical failure, isolation devices, and fires that are initiated internally.

A total of 31 different accident scenarios representing eight different actual phenomena were defined.

So, this slide shows Step 4, which is defining the bounding representative accidents from the list of potential accidents derived from the hazardous condition evaluation. A BRA, sometimes I'll say B-R-A, and I mean bounding representative accident, is representative of a group of accident scenarios that are phenomenologically similar.

The likelihood for a BRA is determined by the sum of the accidents in the group. The consequence of a BRA is determined by the worst consequence of the accidents in the group.

By using this approach to define BRAs, that bounds the risks of all accidents in that group. There were a total of 13 BRAs defined from this demonstration. BRA.

Next slide. This is actually the bounding representative accidents. You can read those on your handout. I'm not going to go over them. But, in general, they consist of impacts of different severities, fires, impacts and fire, non-impact crashes, non-impact package failures and criticality.

Next slide. This slide shows Step 5, which is development of the likelihood for each BRA graded for very large trucks greater than 26,000 pounds were used, when available, to determine the frequencies of different types of accidents defined by the bounding representative accidents. Though, we anticipate the actual weight will be greater than 150,000 pounds. But this is the best available data, and it's likely conservative and prior to a much larger vehicle.

Route-specific data for large truck accidents for the five states of the assumed route, hypothetical route, were augmented by nationwide statistics. In many cases there was not enough route-specific information to develop an accident frequency. So, nationwide data was used to develop split fractions that were used in conjunction with the route-specific data.

Route-specific data is from the Federal Highway Administration. Nationwide data were used from the Motor Carrier Management Information System and the Fatality Analysis Reporting System we call FARS.

The second set of data approaches used to estimate package-specific failure likelihoods: crash events, as we mentioned, human errors, and mechanical failures.

And then a third set was used associated with route-specific hazards such as distance of bodies of water, steep drop-offs, which I'm going to show you on the next slide.

So, this slide shows the assumed hypothetical route from Idaho National Labs to White Sands, New Mexico. Almost entirely interstate along a 1,300 mile route.

The GIS data search scripts and Google Street Views images were used to identify portions of the route where a hazard existed to compute the percentage of the length of those portions to the total length. We can see on the map, I think, that there are bodies of water and mountainous regions; right?

So, we used this to look at two different kinds of hazards, that when I say "this" I mean GIS, of steep drop-offs. If an accident occurs here, the truck and the truck and the package could drop or roll to a lower elevation. This could result in significant impact sustained to the package.

Also, we looked at locations where there was sufficient slope to a body of water deep enough to submerge the reactor vessel. If an accident occurred here, criticality might occur for the, for the demonstration design.

First, a script was written to search for these locations. Then the route-specific very large truck crash rate was multiplied by the percentage of the route where the hazard exists to get a final accident frequency for that, involving that particular hazard.

Lastly, a physical road survey was performed to confirm treatment of identified hazards and to identify locations for safe havens.

MEMBER REMPE: Let me ask a question here. And, again, I'm going with what's in the report that the staff was looking at that. I see on page 192 out of 354, and it's talking about how you calculated the frequency.

And I guess the assumption that concerned me was that you assumed that the accidents are randomly distributed. But, again, I would have to assume you're moving that package around on the side in Idaho. So, that's why I was looking at this because I lived in Idaho.

Along that road to Utah it's well known that there's a portion of the highway that's elevated and curved. And in cold weather it has black ice on it and the semis always roll over. And I'm just thinking that's not a good assumption if that's part of the road you're probably going to be taking.

And is that a common assumption that is used for these types of frequency estimates? Because I don't see a highway analysis, safety analysis, and it kind of concerned me.

MR. COLES: So, we don't --

MEMBER ROBERTS: I had a related question to this, too, which is this regards the number. I was wondering if you looked at the probabilities or accidents because of congestion in a highly populated area versus other places? Or are there some features you can talk about, geographic features, geological features, whatever, are in those kind of areas that are being reported.

MR. COLES: We specifically address the route to go around Denver for that reason, as I pointed out.

DR. MAHERAS: Can I?

MR. ADKINS: Yes, please. Please do, Steve. And it ties to a number of things.

DR. MAHERAS: I'm Steve Maheras at Pacific Northwest National Labs. So, in regards to the routing that was done, we used a tool that generates routes that would be used for spent nuclear fuel. So, for whatever reason, that route through Denver, which is the state-approved route, goes right through the Mousetrap, right through town. Right?

So, we chose to evaluate a route that goes around Denver also as an additional case because of a concern about getting it outside of Denver proper. Right?

With regards to the data used, we have a bit of a problem with the ability to discern accidents on specific sets of roads. We can pinpoint the accident just fine. We know the location. But we need to get the denominator in that equation also, which is traffic volume. And that one tends to be the one that's the tougher nut for us to get is the denominator in the accident rate calculation.

It's, it's straightforward to define the position of the accident, and it's not as straightforward to get the commodity flow to do the calculation part.

MEMBER BIER: I have an additional question, which is probably more for staff than for PNNL.

In this analysis, obviously, this was done for a specific transportable reactor. And you knew most likely at least where it would be coming from or where it would be going, so you could do this very detailed analysis of routes.

In future, if we have transportable reactors for other purposes we may not know at the time where it's origin, even where the destinations are. Or, they may be moved from one location to another.

Somebody recently contacted me with an interest in using transportable reactors hypothetically eventually for fracking, where it might be moved, say, from one oil well to another, you know, in, in the same state, you know, in North Dakota, or in Texas, and maybe in a totally flat part of the country where this kind of topography would not even occur, or where you could never get black ice if it was in Texas, or whatever.

And so, has any thought been given to how you conduct a more generic type of analysis that would have to include the possibility of these kind of routes but wouldn't assume detailed knowledge of exactly which road you were going on and where?

MR. WHITE: Bernie White, NRC staff. So, the easy answer is yes. However, you know, there's a lot of complicating factors with that. You know, typically in spent fuel transportation, packages go anywhere, any time. Or in transportation, the packages go anywhere any time.

If you are using something like this methodology that is extremely specific, that probably would not be the case. You would probably be limited to specific routes, specific locations.

Does that mean that that's the only thing we would ever approve? No. If sufficient number of people wanted something like this, a sufficient number of vendors wanted something like this to be approved for a larger number of reactors to be shipped -- when I say "reactors" I don't mean, you know, five Peles. I mean Pele plus reactor by five, six, seven, eight different companies -- we would probably look to do, consider -- I mean, that would probably be a rulemaking that we would probably consider doing to look at the broader picture.

We have not considered that at this point because we don't have enough data to warrant us to do that, given what we've heard from transportable micro-reactor vendors.

CHAIRMAN BALLINGER: So, Dennis has got his hand up, and I don't know for how long.

MR. BLEY: Oh, for just a little while. Thanks, Ron. I have two questions I would like you guys to talk through a little bit. The first one deals with the bounding representative accidents. And Chapter 5, pretty thorough as I read it front to back.

But my first question is what kind of measures did you guys do from kind of an overview or structural point of view to enhance completeness of this accident, being very careful that you haven't left anything out that could matter?

The ones you have here are described really well for me. And then, these words have come up a bunch of times, and maybe you can clarify just what you mean. A script was written to find this or that. Tell me about what that means?

MR. COLES: Well, what we're trying to say is about the script. And, Steve Maheras, feel free to jump in. But, because we're using GIS, right, data, there's a way to search the data. And we were interested only in particular locations where specific, you know, parameters existed that we thought were hazardous. One is a steep drop. If you had an accident at this location, go off the road, you would drop to a lower elevation. The other one had to do with dropping into a body of water.

Steve Maheras, would you like to add to that?

DR. MAHERAS: Yes, yes. So, instead of trying to find those by hand, using a map perhaps, we used GIS. The script was merely a tool of convenience to search through the GIS data to find the locations of concern.

MR. BLEY: Okay, that makes sense. I've never had a chance to look through that and do that myself. But I guess that database is searchable for these things. And that's what you did. It's like a little program to look for the places where these conditions might exist.

DR. MAHERAS: If you are clever with tools like Python, et cetera, yes.

MR. BLEY: Okay. And the other question is, from a high level point of view what --

MR. COLES: Yeah, Dennis.

MR. BLEY: -- you've done is complete as possible?

DR. MAHERAS: Right. So, Dennis, our intention using, you know, the hazard analysis approach was to be comprehensive. And in the back of the report, if you had a chance to look at it, there is appendices that provides all the hazardous conditions that we identified in a group of subject matter experts.

MR. BLEY: Uh-huh.

DR. MAHERAS: And there's about -- I think there's about 50 pages of accident scenarios, really, there. We screened a number of those out qualitatively because they didn't produce enough impact for the package, or they just were so incredibly low frequency that we didn't carry them forward.

Then of the ones that were left we organized those into 31 accident scenarios, which are listed, I think, on Table Five-four, if memory serves me correct.

Then, from there we aggregated those 31 down to 13 of bounding representative accidents. We feel that we have looked across the entire landscape for accidents, and that these bounding representative accidents are bounding enough and representative enough of accidents that can occur.

MR. BLEY: I guess where I was pointing to is the breadth of the search by your large number of experts is the basis.

What did you do to try to make sure -- and this is a hard thing to do sometimes -- try to make sure the experts have considered this broadly enough to take off all of the important possibilities?

DR. MAHERAS: Right, I understand your question, Dennis. I mean, that, that is the purpose of hazards analysis. And we did a couple things.

Now, the design actually provided that hazard analysis of a stationary route. So, we, number one, we considered all those.

And, number two, we started with a large checklist of hazardous conditions and energy sources. And we considered each one in turn.

And then that's how we came up with the 50 pages of hazardous conditions that, that are in the appendix. We tried to include in the group people with the appropriate subject matter expertise, people that understood design, people that understood consequence analysis, people that understood the fire hazards and the chemical hazards, for example.

MR. BLEY: Okay. Well, that's probably as good as you're going to do. You know, hazard analysis, I agree, it's the purpose. But it covers a plethora of things that one can do. Some of them help you be very complete, other ones not so much.

So, that's a pretty good answer for now. Thanks.

DR. MAHERAS: Great.

MEMBER REMPE: This is Joy. And I want to bring back my point again about the way you calculated the frequency for the accidents.

If you go to page 182 you, you do say, hey, it's only going to be point -- 5.9 miles, about .46 percent of the 1,289 mile route. And so, then you look through and have, that you have the total number of accidents. And then and you multiply that by -- and say that there is about 3.9 timber mines, 7 miles potential for an accident, per your frequency. And then you multiply that frequency by .46.

And that's my problem is, okay, you figured out what fraction of the distance is where you can have a drop and rollover, but then you took that fraction of the distance and multiplied it to get the frequency of an accident there. And to me, you've got to go through that distance. And I don't think the math is right.

MR. COLES: Well, let me say something

real quick to see if this helps. We did -- I mean, I understand your point. Your point, I think, and correct me if I'm wrong, is that the accident rate probably varies along the route. And I think that's your point.

So, so what we did is we didn't -- Steve explained that. It's really hard to find the actual accident rate across any segment of the route. So, we used the aggregate crash frequency for the entire route.

MR. ADKINS: We should probably speak to the fact that there's tremendous inherent and tremendous conservatism in the numbers that we used because we used, like, small truck accident frequencies as opposed to something that would be of the concepts that we're talking, upwards to 150,000 pounds, that are heavy, heavy haul and things of that nature, just to induce some conservatism.

And one of the reasons for doing that, which I would let the experts speak to this, is the fact that there was kind of a void in some of these heavy haul truck accident magnitudes, frequencies, things of that nature, that there was an absence of a lot of that data, primarily due to the fact that they're so infrequent in comparison with the numbers that we've used.

Steve, you may have something you want to say?

DR. MAHERAS: Yeah. Yeah, so when we say "large truck," right, that's a 26,000 pound truck. We expect a Pele-carrying truck to be around 150,000 pounds or so.

Trucks of that size require state permitting for every state that they go through. That requires a examination of the route to make sure that the infrastructure can handle that load, both from a capacity of the road, overhead bridges, et cetera.

So, we might say large trucks, but they're not Pele large trucks when you talk about the accident rates. And those accident rates tend to be dominated by trucks of approximately 80,000 pounds and less because of the increased permitting requirements that those very heavy loads have.

MEMBER REMPE: So, again, I'm not an expert in highway transportation accidents, but it, to me, it seems -- and I'm sure your numbers are conservative -- but if the staff's looking at the methodology, it just, something seems a little strange that you could divide those frequencies by the fact that there's only a small fraction of the road where you're concerned. It seems like you've got to go through that fraction of the road.

And, again, I'll leave it there, but it just doesn't sound like it's right on how to estimate the frequency because I've got to go through that section of the road to find a different route. But, anyway, I'll let it go there.

MEMBER BIER: Yeah. One other comment.

If I understood correctly, it sounds like you're taking kind of the overall accident frequency for the entire route, which I understand why you have that data, use that data. But there may well be correlations where the part of the road with the steep drop-off above the bottom body of water may be the part where the accident frequency is highest because you're using some curvy route, and the straight shot through a desert that's averaged in with it may have a very low probability of accidents.

And that correlation, I don't know whether that correlation is derivative. And I'm also not a transportation expert. But it seems worth looking into.

DR. SCHULTZ: Steve, this is Steve Schultz.

The question associated with -- I'm over here. The question you associated with your last response, you indicated conservatism associated with the assumptions that you have, you have made. Do you have a sense on the degree of conservatism that that imparted to go through this.

DR. MAHERAS: It's very difficult to tease out from data accidents for loads of 150 or so thousand pounds. So, I would say that we are conservative by probably a factor of 100 to 1,000, just because there are so few accidents involving those very large loads because they're escorted fore and aft, because they have permitting requirements, because in general they're required to us a higher quality road, et cetera.

DR. SCHULTZ: That's fine. Without quantifying it, it's an important feature of the overall evaluation. When we look at the, at frequency consequence plus, we're going to have questions about uncertainty associated with where the bullets land.

So, that's good information to know. Thank you.

DR. MAHERAS: Yeah, and --

MR. BLEY: This is Dennis again. I think you guys need to be really careful about these kinds of conservatism. I think the one you just described, yeah, that's pretty strong, that you're taking data from a lot of different kinds of trucks. And probably the class you're looking at has lower accident rates.

But what Vicky brought up is what I was hanging on. Most of the things you're concerned with are occurring places where the roads are a little more winding, where I would suspect accidents are quite a bit more likely. So, that's the opposite side of it.

So, climbing in a blanket while you have conservatism without some more to back it up seems a little bit of a stretch.

CHAIRMAN BALLINGER: This is Ron Ballinger again. The boundary line is about 80,000 pounds. If you look at standard tractor-trailers, on every highway it's usually around, the upper limit on weight is about 80,000 pounds. Above that, you have to do this special permitting.

And when they do the special permitting, if there's a curve or something like that, which that route is pretty well analyzed.

PARTICIPANT: Significant administrative requirements, yes.

CHAIRMAN BALLINGER: And so, you know, it makes a difference.

MR. COLES: Again, right, this is a

demonstration. And actually what we've done in terms of likely, developing likelihoods is quite sophisticated.

All right, Dennis.

MR. SHORT: Yeah. This is Steve Short. Just, again, we would emphasize the whole reason for a big part of PRA is there is uncertainty in the data. Right? That's why you do sensitivity analysis, that's why you do uncertainty analysis, to try and get your hands a little bit around where you might be uncertain, and how that might change your risk insights.

MR. COLES: Yeah. We'll actually show you an example of the uncertainty analysis that we did on that crash rate.

So, am I ready to go forward?

CHAIRMAN BALLINGER: Yeah. We better proceed.

We're halfway through the slides, and three-quarters of the way through the time.

MR. COLES: All right, let's go.

CHAIRMAN BALLINGER: Or two-thirds of the way through the time anyway.

MR. COLES: Let's proceed.

Question?

CHAIRMAN BALLINGER: These are the kind of questions you can be asked.

MR. ADKINS: Very good questions.

MR. COLES: So, Step 6 is to develop the bounding consequence analysis for each BRA.

Again, the estimated effective radiation dose pathway, which I'll show in the next slide, is based on Appendix 1 of IAEA SSG-26, with refinements. Like I said, mostly account for the public receptor, because they put the receptor at one meter. We chose to put our worker at one meter and put our public receptor a little further away.

To determine the source term, so that's the material that gets released, right, the traditional factor formula commonly used in DOE and NRC, because safety analysis was used for both worker and public according to whatever the accident phenomena was, impact or fire for example, you can see the definitions for the factors at the bottom of the slide there on the right if you want to take a look.

For this demonstrations, factors were used -- values, I should say, were used from NRC and DOE handbooks for applicable forms of the radiological material. And where expert judgment was used, values were selected with an object to be bounding to account for uncertainty.

By recognizing that the TRISO fuel particles are much smaller and resistant to failure than standard light-water reactor fuel.

So, this slide is about developing consequence for each BRA. And the diagrams there on the right, those represent the radiological dose pathways.

The external photon dose is external dose due to released material. But we added contribution from other material from a package with the degraded shield. So, in our collisions we degrade the shield or we take away the external shield.

External beta dose is the external direct dose, the skin contamination due to released material.

The inhalation dose, that's the QC, is calculated using an source term, which I show on the last slide, and a human uptake rate. Skin contamination QD is calculated from equivalent skin dose. This is from handling debris per the guidance in the SSG-26. Wasn't used towards the risk evaluation guidelines because that's not the way SSG did it. We're going to talk about this later.

Because we assumed in our demonstration that anyone handling debris would be trained in radiation safety, and use protective clothing.

Neutron dose is not included in the fuel system, and was determined by Q analysis to be a minimal contributor for released material and is, in any event, dominated by the gamma contribution for this demonstration.

Other pathways excluded by the Q system are suspension shine, drinking water ingestion. But because they're not significant contributors for irradiated fuel, will likely be mitigated, and would likely be mitigated by response.

And then you can see on the bottom there that submersion pathway was excluded because the release is outdoors. So, there would be a high level of dilution on the placement site.

MEMBER HALNON: Just a quick question.

Are you going to talk about the meteorological conditions that were seen? Because I don't know how you can survey about worse case.

MR. COLES: Steve Short, can you help, please?

MR. SHORT: Yeah, what we did is we used, we used the Q system assumptions of that, which are set up to be conservative. Because our receptor is so close to the package you cannot use a standard kind of dispersion model. Right?

MEMBER HALNON: Right.

MR. SHORT: I mean, those are only applicable to things half a kilometer approximately further out.

So, we used the Q system, which has built-in assumptions about that and are specifically defined to be conservative.

MEMBER HALNON: Okay. So, it's like a own source ground level?

MR. SHORT: Yep. That's right.

MEMBER HALNON: A given one?

MR. SHORT: That's right.

MEMBER HALNON: Okay.

MEMBER MARTIN: As you're looking at the consequences, things change throughout the route with the assumptions. Is there built into your structure a -- I'm about ready to go outside my BRA assumptions, therefore I can't do it, I've got to stop? Something to that effect. Or where there's a -- I mean, a nuclear plant has continuous monitoring of systems. And if we're outside the design basis we take actions immediately to get back within it.

It's kind of hard to turn around a 100,000 pound truck and say, well --

MR. COLES: Okay. Harold, did you want to talk about the safe havens?

MR. ADKINS: Sure. And Virgil probably would be the best to speak to that.

But there's a couple of things that we took into consideration, one of which is the way that the example, again example, pathway and process, of what the compensatory measures that would be established as part of that in consideration of the weather and the environment, inclement weather impact and things of that nature.

And then we've also taken into account that likely, you know, in the case for Pele would be Army managing that asset and relying on safe havens that Virgil could speak to a lot better than I can. But those would be also considered first.

MEMBER MARTIN: So, you'd take actions to put it back within, --

MR. ADKINS: Yep.

MEMBER MARTIN: -- for lack of a better term, design basis?

MR. ADKINS: Keep it within its design basis. That's correct.

MEMBER MARTIN: Okay. And one last question while I'm talking. I know you addressed recovery in the report. But I didn't really see a lot of detail on recovery. You assume that they're trained in radiological protections, that your people were covered.

If you, you know, are familiar with heavy rescue and the recovery actions, the first responders are probably --

MR. ADKINS: Right.

MEMBER MARTIN: So, it's going to be there for a while. And then you tend to get very intimate with the load when you're trying to irradiate, get sometimes four, five, six cranes in, you know, prompt and address. In addition to that, you're probably closing down a highway for a long time.

Is all that type of consequence to the public taken into consideration, and consequence to the workers from a dose rate perspective? Is that all taken into consideration, some kind of bounding effect?

MR. ADKINS: So, this isn't to slough things off at all by any means. But one of the things that we very first we consider as an applicant that comes to the NRC with their SAR, they're going to have to have it on an accident, an accident but as well as an incident recovery plan. Right?

MEMBER MARTIN: Right.

MR. ADKINS: And it's got to be highly -- oh, sorry, Pete -- highly detailed, right, to even obtain the licensing. And that was slightly beyond the scope of what we would consider because we don't have a lot of specific detail that we could integrate into this.

And the other thing, too, you run the risk of migrating off a technology neutral application; right? So, and we're still in the process of showing pathway and hardened process. Right?

MEMBER MARTIN: Okay. So, it's thought process that's got to be taken into consideration.

MR. ADKINS: Exactly.

MEMBER MARTIN: But not in this project but certainly in the big picture.

MR. ADKINS: Absolutely. Absolutely. And not something that the NRC they would -- and not to speak for the NRC -- they would be looking for that as part of the development of the safety basis and things of that nature as well.

MEMBER MARTIN: Okay.

MR. ADKINS: Gentlemen, if there's anything that you'd like to add to what I stated, please, or any clarification you'd like to provide.

DR. MAHERAS: So, so we have thought somewhat about a recovery plan and what that would look like.

As an example, shipments to WIPP have a recovery plan that describes the equipment necessary, the procedures necessary, et cetera.

Now, of course, content handled, though, is not the same thing as a micro-reactor. So, it would have to be modified, extended, adapted, et cetera. But you might expect to see the same kind of contents, just not the same kind of details in, in the recovery plan.

MEMBER MARTIN: Thank you.

MR. COLES: So, if we move to the next slide, this shows Step 7, which is compare the risk results with the evaluation guidelines. So, after both the likelihood and frequency I've developed for the BRA, the results are compared to the guidelines, the right-hand side of the slide. Dose rates, that depending on the accident frequency, the dose limits can be higher or they can be lower.

If the accident frequency is between 1E to the minus 5 and 1E to the minus 6 per year, as shown in the red text on the top on the right-hand side, and the dose limits are between 5 and 25 rem for a member of the public, and 25 and 100 for a worker, as shown in the green text. However, if the accident frequency is higher, then the dose limits can be lower; right?

So, for example, if the accident frequency is between 1E to the minus 4 and 1E to the minus per unit, shown in the red text close to the bottom, then dose limits are between 1 and 5 rem for a member of the public and 5 and 25 rem for a worker, shown in the green text on the bottom.

Next slide. This is Step 8, which is to assess the sensitivity of the PRA modeling assumptions on uncertainties. Sensitivity studies were performed to address the impact of uncertainty and assumptions used in the model. So, lists of model assumptions and bases were documented for the major elements of the PRA. And these were evaluated, first by determining which sources of uncertainty could be screened qualitatively. Plus, they didn't really have a impact on the risk conclusions.

Then quantitative sensitivity studies were performed to characterize the impact on the sensitivity using conservative estimates in the inputs, rather than using the baseline assumptions.

These results were then compared to the risk evaluation guidelines. I'll show you an example of a sensitivity study in just a bit.

Then, also, a limited parametric uncertainty analysis, typical PRAs, was performed for this demonstration application. Risk results from PRAs typically are reported as mean values when comparing to risk evaluation guidelines per guidance section NRC Reg Guide 1.200, and the 2008 RIDM report.

I say limited because data for parametric analysis for transportation PRAs is at this point limited. And I'll show you that, that uncertainty analysis in a little bit.

Next slide. This is Step 9, which is to assess defense-in-depth, and Step 10, which is to assess safety margin. As you know, defense-in-depth is a design, an operational philosophy that calls for multiple layers of protection to prevent and mitigate accidents. Multiple layers identified for the demonstration application are shown on the slide. It's one of the multiple physical barriers to prevent release. Passive features, the fact that the PRA shows a risk, administrative controls, and accident recovery plans.

Safety margin is a measure of the conservatism that's employed in the design process to ensure a high degree of confidence that it will perform the needed function, typically to demonstrate adherence to acceptable codes and standards.

This slide shows the results for one of the bounding representative accidents of BRA 2, which is a fire only that originates from outside the transport container. There's no crash involved. This could be an engine fire, or a wheel fire, or some other fire that grows to involve the diesel fuel. And then the fire propagates into the transport container.

So, just if you could read this result table, the red text in columns two and three show the dose to the worker and public. The blue text there in the fourth column shows the accident frequency.

But when you combine these results and compare to the risk evaluations criteria, in the guidelines in the far right-hand column you can see that the risk from this BRA is acceptable. We see there's more details in that slide such as the contribution on the TRISO fuel itself. The contribution from radioactive material in the core structure and the cooling system are also included.

The next slide. This slide shows the risk results for the highest case. This is BRA 3. It's a hard impact. It caused the leaks to release radioactive material and degrade shielding. It includes collision with heavy vehicles and unyielding objects like bridge abutments.

Again, just to reverse how this works, if you look at the red text in columns two and three, show the dose to the workers and public. The blue text there in the fourth column shows the accident frequency. If you compare that to the risk evaluation guidelines you see that the risk using our proposed risk evaluation guidelines is unacceptable, both public and the worker.

Options to mitigate this risk are discussed a little bit later in the sensitivity study.

MEMBER KIRCHNER: This is Walt Kirchner.

Clarification: That's for an operating reactor?

MR. COLES: No.

MEMBER KIRCHNER: End of life fission product inventories?

MR. COLES: This is a -- the baseline conditions were they operate, the reactors operate for three years, and it has decayed for 90 days.

That's a good question.

MR. ADKINS: So, definitely end of life, yes.

MEMBER KIRCHNER: Thank you.

MR. COLES: So, this slide presents a summary of the demonstration PRA risk results because the risk evaluation guidelines, the blue is the public, the orange is the worker. And you can see, right, we were talking about this earlier, that just the one accident falls above the blue line, and somewhat above the blue line.

The bottom of this slide states that certain BRAs are not presented in the graph. These are the criticalities.

Two of the BRAs are flooding criticalities. One is from falling into a body of water as a result of a crash. And then the other is fire water inundation.

We did calculate the frequencies, actual frequencies for these accidents. They're extremely low.

See, on the right-hand side of the chart.

And so, we didn't, for this demonstration we didn't, we didn't calculate the consequences.

MEMBER BROWN: Excuse me.

Why are bodies of water so extremely low? I just think about cars going across the Chesapeake Bay Bridge where there are frequent occurrences of total blockage due to accidents, wrecks, et cetera, et cetera, during the year. And so and there's a lot of water.

MR. COLES: Yeah, yeah.

MEMBER BROWN: Wondered if something like this would go off that and include whatever.

MR. COLES: It does, yes.

MEMBER BROWN: And so that seems to be a little bit.

MR. COLES: Well, for this route, remember, that's what we described earlier is we, we actually compute the likelihood of an accident through very complex processes in GIS, what that likelihood is.

MEMBER BROWN: Yes. I meant to ask that earlier, what does GIS mean? I missed that. Is that just a compendium of population data?

MR. COLES: What's GIS?

DR. MAHERAS: So, it's a Geographic Information System.

MEMBER BROWN: Oh.

DR. MAHERAS: So, so we have two or three that are used on the project. One is to define bridges and bridge heights.

A second one is to define the soil types along the routes. And that speaks to the hardness of the target that might be impacted during an accident.

And a third provides us the transportation routing that would be used by the package.

MEMBER BROWN: I guess the reason I ask it is that roads and other byways there's, could be a lot of room on either side of those bridges that are all very, very restrictive relative to what they can do maneuvering these very tights. So, I would have thought bridges would -- I mean, you have to cross bridges no matter, almost no matter where you go.

DR. MAHERAS: Yeah.

PARTICIPANT: We crossed the Snake River a number of times. And we did identify every location where we crossed a body of water, not just rivers, streams, but any body of water that could exceed 5 meters.

DR. MAHERAS: The other thing is in transportation, the first rule --

CHAIRMAN BALLINGER: Can you get closer to the microphone?

DR. MAHERAS: The first rule is if it doesn't fit, it doesn't ship. And so, shipments that are what we colloquially call high, wide, and heavy -- and that's kind of where we are with this reactor -- we would have to be permitted by the state.

And those would, those permits look at the state of the state of the infrastructure. And they might preclude shipment on routes such as the Bay Tunnel complex.

Oftentimes, those kind of areas have HAZMAT restrictions that are invoked by the state. So, we would need to consider that, and likely stay off of those restricted routes.

MEMBER BROWN: Okay, thank you.

CHAIRMAN BALLINGER: I would presume, by the way, that BRA 3 and 4, 4M, that would invoke compensatory measures.

PARTICIPANT: Oh yeah.

CHAIRMAN BALLINGER: So, this is a little bit misleading if you don't understand that that's what was happening and move those.

MR. ADKINS: Correct. Back into the shade.

MR. COLES: And we're going to talk -- that's a perfect segue to where we're going on the next slide.

MEMBER ROBERTS: Before you move on to that.

MR. COLES: I'm sorry.

MEMBER ROBERTS: That was a chance to

address my question on cliff edge effect.

MR. COLES: Yes.

MEMBER ROBERTS: That criticality is not showing up on this slide because it's below the probability of frequency threshold. But I'm just wondering why you think it still has a cliff edge effect?

MR. ADKINS: I can at least initially speak to that.

So, one of the reasons is there's some uncertainty associated with the example that we're using because it originally was slated, and the anticipation is that anything going over the highway would have transportation poisoning to mitigate any kind of criticality event even if it were to breach and take on water.

So, in this particular example, since it's not going offsite, it doesn't have transportation poisoned. And we thought that that wouldn't really be a good example, it would drive things off in a district that would be hard to explain and really draw some point of explanation in the pathway and process.

MEMBER ROBERTS: In effect, it would have a compensatory measure to ensure the criticality is not going to happen in these scenarios?

MR. ADKINS: Yes.

MR. SHORT: It might not just be compensatory. It could be the design portion.

MR. ADKINS: That's right. Absolutely. Thank you, Steve. Appreciate that.

MEMBER BIER: One other point with regard to compensatory measures -- this is coming back to something we discussed a few minutes ago -- is presumably there could also be compensatory measures that preclude shipping when there are storms forecast, to not encounter the worst risk.

MR. ADKINS: That's, that's an excellent point, Vicki. And to that end, within the report we make only an example that quite a few compensatory measures that we would offer up, and the reactor vendors are cognizant of those, too. In fact, some of ours were derived directly from the reactor vendors.

Thank you.

DR. MAHERAS: So, so when you actually ship fuel and waste, that is a very common compensatory measure, you do not ship when the weather is forecast to be bad, or you ship upon an alternative route that is not subject to the bad weather. So, that's a very common compensatory measure.

MEMBER REMPE: So, I have not been

watching because I was interested in the topic. But when folks over here on this table speak, you need to say your name for the court recorder. And I know you probably will say it five times before the end of the meeting. But it's important.

DR. MAHERAS: Oh. This was Steve Maheras who just spoke. Sorry.

MEMBER REMPE: Thank you.

MR. ADKINS: Sorry, Joy. Thank you.

MR. COLES: So, shall we move to the next slide?

MEMBER BROWN: One other question relative to talking about the weather, excuse me, the weather routine.

I was just -- this is kind of a practical thing. In this area there's a lot of hurricanes that come floating across Florida and then go up the coast. And they are not even predicted to even touch as far north as we are. And all of a sudden six hours later, whoops, the winds change, now we're getting inundated.

You said forecasts. And forecasts can be very, very problematic and deal with certain types of circumstances. Is there any way to take that into consideration or do we just -- is that a one day long, you know, in advance forecast? Because those can be not correct.

DR. MAHERAS: So, we would typically, when you actually ship fuel and waste, look at the near term forecast a day or two, and also longer term forecasts along the route.

But hurricanes, yeah, we would like to avoid those, most definitely.

And this was Steve Maheras who just spoke.

MR. PEOPLES: So, Virgil Peoples, INI.

I know we talked about earlier safe havens. I just wanted to clarify for the team.

So, safe, safe havens are typically DoD installations that you would move radiological shipments to so you can get them away from the public. Typically, they would be stored on that DoD installation in a safe location where they would have it in the warehouse type of location where it would be safe from anybody around on a particular installation.

MR. COLES: Okay. Shall we move to the next slide now?

MR. ENGLAND: This is Jeff England from NAC. Can I make a comment?

MEMBER REMPE: I'm sorry, are you supporting PNNL? Okay, Gen V --

CHAIRMAN BALLINGER: She's saying are you a member of the public?

MEMBER REMPE: Yeah. There's a time for public comment at the end of this meeting. I'm the Chairman of ACRS, and that's why I'm answering.

MR. WHITE: So, so SCO has a contract with BWXT. BWXT has a contract with NAC for package approval.

MEMBER REMPE: If PNNL or later if NRC wants to ask for their assistance, that's fine. But not just to speak up. It's up to the person that's got the floor.

Thank you.

CHAIRMAN BALLINGER: So, let's continue.

MR. COLES: Let's continue. The next slide.

This slide is performance sensitivity studies. As I said earlier, selection definition of sensitivity cases were performed based on comprehensive examination of a specific list of assumptions that bases that were used in different parts of the PRA, like the hazards analysis, the likelihood development, and the consequence analysis.

Possible compensatory measures listed for the demonstration design to reduce and mitigate risk were also done in this way.

The studies we did on this are there.

In the next slide I'm going to show you an example of sensitivity studies, how you can use it.

So, this slide presents the results for BRA 3. Remember, that's the hard accidents, or that's an accident that exceeds the risk acceptance guidelines. It explores the impact that delay time after reactor shutdown in transport has on risk.

So, you see that the red text there in the second and third column, that's associated with the baseline case, so that's a 90-day decay time. And you can see that the guidelines are exceeded in that case for both the worker and the member of the public.

If you look in the yellow highlighted numbers in the second and third columns associated with decay time on one or two years, you can see that the risk evaluation guidelines are not exceeded.

So, accordingly, this sensitivity results shows that if the delay after shutdown is increased to a year, then the risk for all the highly representative actuals is acceptable.

That's one way to use your sensitivity analysis.

The next slide I'm going to show you, this slide presents the results of our parametric uncertainty analysis. In general, like I said, there's, there's not a lot of data to perform parametric uncertainty analysis. As we've heard earlier, there's even variations along the route that you might take into consideration.

However, a limited uncertainty analysis was performed on very large truck actual data. And in the limited analysis we increased the actual frequency by 41 percent to match the worst yearly rate of the five states the route covers for the years the data was compiled. And this was an effort to consider the spread of the accident data.

The limited analysis did not change the conclusions about the risk to the BRA with this, this one exception. So, this is BRA 4, a medium impact accident. So, this is in the uncertainty analysis if you increase the accident frequency by 41 percent, then you would -- the risk would be unacceptable when you compare it to the risk evaluation guidelines.

MEMBER BIER: A minor comment. First, I really like the sensitivity analyses that you did in your study. I thought that was very helpful. You didn't spend a lot of time on that here.

I would say that this also I would characterize as a sensitivity analysis, not an uncertainty analysis.

MR. COLES: Sure.

MEMBER BIER: It's a different type of sensitivity, but it's basically saying what if this number was higher.

MR. COLES: Right. Understood.

MEMBER BIER: Minor comment.

MR. COLES: So, this slide presents key insights from the demonstration PRA results of sensitivity studies that could be important if this were an actual application versus a demonstration.

But one of the major insights was that allowing, like we said, the core to decay up to one year -- excuse me -- after it's been in operation for three years, would result in an acceptable level of risk for all the bounding representative accidents based on the proposed risk evaluation guidelines.

The risk conclusions about BRAs are not sensitive to the uncertainty in estimating the source term factors. We moved this quite a bit, for this demonstration anyway.

Risk conclusions about BRAs are not sensitive to increasing the accident duration from 30 minutes to an hour, for this demonstration anyway.

And the risk conclusions about BRAs are

not sensitive to decreasing the distance that the public is to the accident, except for in one case where the guidelines are slightly exceeded.

The next slide is the final slide. This is our summary slide

So, current NRC regulations provide a feasible regulatory pathway for licensing a first-of-kind transportation of a micro-reactor with irradiated fuel.

Proposed workable risk evaluation guidelines were developed that are compatible with the Q rules proposed in the 2008 NRC RIDM report.

The risk informed PRA crunch can be used to support an application to NRC for approval of a TNPP package containing irradiated fuel.

And, number four, the demonstration application of this approach for a hypothetical single shipment per year of a Pele micro-reactor has shown that the proposed risk evaluation guidelines can be met.

That is the end of this presentation from PNNL.

CHAIRMAN BALLINGER: Thank you, any questions by the members?

MEMBER KIRCHNER: Ron, are you going to

ask for questions from the members?

CHAIRMAN BALLINGER: That's what I just did.

MEMBER KIRCHNER: Okay, may I make one?

CHAIRMAN BALLINGER: Of course.

MEMBER KIRCHNER: I, first, to PNNL people and the staff, this looks like a reasonable, well-thought-out framework for evaluating the transportation of micro-reactors. I want to raise the bar a little though, and maybe it crosses over into policy, but it also impacts public safety, which is our concern.

It's one thing to do this for national defense and declare national emergencies like a Pele Project. It's another thing to do this for commercial applications. A wide deployment of micro-reactors presents proliferation risks, not only of nuclear material, but proliferation of risk to the public. And there are options, and the most important one is, I think the framework even in the commercial sector could be used for the deployment, that is a fresh core being shipped out to convince the regulatory agency and the public that the risk is acceptable.

But there's no reason why design options to retrieve and recover using licensed casks for spent nuclear fuel cannot be pursued and achieved. So, I just make that as a statement because there's a big difference between national defense and commercial deployment. And there are design options to recover the fuel, spent nuclear fuel.

It may not fit the model that some of the vendors would like, but there are means to protect the public. That's it, Ron.

CHAIRMAN BALLINGER: Thank you. Charlie?

MEMBER BROWN: Yeah, I forgot to ask this question on the first slide, or third slide where you talked about the rating of the micro-reactor would be somewhere between one and five megawatts electrical. And I guess my question had to do with, I just did a little thought process, in my neighborhood all the new houses that are being torn down and built run about 72000.

And they're all full electrical heat pump, there's no gas on all the new ones, the way they had to be put in. So, that's about 14 houses, and that's -- 14 houses is not a lot, if you go to 5 megawatts, it's 70 houses. So, what determined the megawatt rating, what would their uses be?

PARTICIPANT: So, first of all this is a demonstration, Project Pele, I'm going to let our --

(Simultaneous speaking.)

PARTICIPANT: --- average house using seventy kilowatts.

MEMBER BROWN: But if you look at the new house next door to me, it's 5000 compared to mine, which is 3000 square feet. It's two heat pumps in order to keep it running, they can't run the bathrooms without running because it's below grade, they have to pump the sewage out up into the sewer system, and they're fully wireless with the maximum internet they can have, I pick up their wireless in the house.

So, they are pumping out, and when it was about 35 degrees out, their heat pumps are running 24 hours a day because you can't get any heat out of 35 degrees, that means they were all on resistance heating. So, those are the type of houses -- I'm not in favor of that, but that's just the way they've destroyed the neighborhood.

MR. WAKSMAN: Yeah, I would say first of all that as much as I think some people on the internet would like to have a nuclear reactor in their basement, I don't think that's going to be a business case.

MEMBER BROWN: No, I was just trying to say what applications business wise was this envisioned to service, that was my --

MR. WAKSMAN: So, for the Department of Defense, the applications that we're primarily looking at are things like missile defense systems, over the horizon radar systems, and --

MEMBER BROWN: So, isolated units.

MR. WAKSMAN: Yeah, they tend to be in the one to five megawatt range, but we tend to specifically look at micro-reactors, either austere locations, places where it's difficult to get power to, or places where you just really, really have to have power 24 7. Because from a business case, and just from a physics perspective, micro-reactors are going to be significantly more expensive per kilowatt hour than a larger reactor.

So, you're not going to do this just to support a larger grid. It's going to be for a really specific application where it's either in a very remote area, or you really cannot afford to lose power no matter what, and it's on some sort of little micro grid. So, I think those would tend to be the application.

So, the companies that are looking at using micro-reactors for non-defense applications are looking at things like remote mining, and things like that. Probably not being deployed around here, where we are right now.

MEMBER BROWN: But from a cost standpoint, the only issue with remote mining, I could understand that, but a one to three year full power operation is pretty -- the cost, and then you take that one out and put in a new one, it's like having every two or three years, is that economically -- has that been factored into the thought process?

MR. WAKSMAN: So, I would think that seeing as how these reactors, just understanding from our development time, you're not going to want to move these reactors very often if you want to have a business case, just because of the amount of time and effort involved with moving them.

MEMBER BROWN: Well, replacing, I mean the mining thing might be there for 25 years, and therefore every 3 years you have to bring in a new micro-reactor. I understand the need, they need power.

MR. WAKSMAN: Well, the three year requirement is a requirement that we chose to set for the Pele prototype. It doesn't mean you couldn't design a micro-reactor that had a longer lifetime.

MEMBER BROWN: And still ship it.

MR. WAKSMAN: Yeah.

PARTICIPANT: I would comment too, the Project Pele application has some very stringent performance requirements and envelopes that they're trying to achieve that are slightly different than like an installation energy application or what have you.

MR. WAKSMAN: Yeah, our reactor module, without getting into anything proprietary or CUI, there's very little uranium in that core, it's a lot of fueling, and it's because we're looking at a very specific example, needing to move it in a specific time. I would think a commercial micro-reactor would be designed with significantly more uranium in a core, and a longer shipment time.

MEMBER BROWN: To get greater utilization time.

MR. WAKSMAN: Well, you would allow it to sit there for probably months before you moved it again to allow the dose to come down naturally rather than just trying to shove it in.

PARTICIPANT: And operation duration, yes, as well.

MEMBER BROWN: Yeah, obviously.

MEMBER PETTI: So, Charlie, there are

designs out there for micro-reactors that I've seen that are longer lived than this.

MEMBER BROWN: I'm just trying to get a calibration.

MEMBER PETTI: There's some that are eight to ten years.

MR. ADKINS: One of the things I breezed over, and I apologize, is the fact that we selected Project Pele primarily due to the fact that Jeff Waksman sponsored us to do that. But also it's probably one of the first out of the gate that we're going to have to grapple with, and figure out something like it, something fairly close to it, because it is fairly close to completion.

Or nearing more than other designs, and so we took that as a primary example to make and work with. So, it was merely a select.

MR. WAKSMAN: I mean, we have, really very high confidence at this point of exactly what Pele is going to weigh, exactly what the materials are. Whereas I think a lot of them, micro-reactor vendors out there have not really thought through that much what it's going to look like. So, it's a useful one to model, but again, as I mentioned at the start, we want this to be much broader just as a principle.

MEMBER BROWN: Okay, thank you.

CHAIRMAN BALLINGER: Okay, we've got to come back to sanity.

MEMBER BROWN: Are you saying my question was not --

CHAIRMAN BALLINGER: A couple of things -- yes.

MEMBER SUNSERI: Hey, Ron, I had one more question if you don't mind, if we have time.

CHAIRMAN BALLINGER: Fine, okay.

MEMBER SUNSERI: Just real quick then. I'm not sure I understand my colleague's comment about risk of commercial versus risk of the military deployment or emergency response. I mean the probability is 50 percent, if I flip it 1 time it's 50 percent, if I flip it 1000 times it's 50 percent, and the consequence is the same. So, is it really more risky if you shipped it more? I don't think so.

MEMBER KIRCHNER: Well, you just cumulatively, Matt, increase the risk in exposure to the public. Again, I think it's --

MEMBER SUNSERI: I think it's the probability, right? I mean all the precautions are still the same. If I ship it one time, I ship it a thousand times.

MEMBER BIER: Yeah, but if you drive once in your life your chance of getting in an accident is very small, if you drive every day it's much larger.

MEMBER SUNSERI: You're telling me if I submit enough lottery tickets I'll eventually win, I guess, right?

MEMBER REMPE: Go for it.

CHAIRMAN BALLINGER: So, anyway, we've got a couple of things here, we're behind. We have a hard stop at noon, and that mitigates against us having any break at all, but I would get executed, terminated if I didn't do that. So, we'll have to take a break until 11:00 o'clock, and then we'll pick it up then. Before we do that, we thank you very much for a very complete presentation, thank you.

(Whereupon, the above-entitled matter went off the record at 10:51 a.m. and resumed at 11:00 a.m.)

CHAIRMAN BALLINGER: Okay, we're back in session, and Bernie, you're next, and then others.

MR. WHITE: Yeah, I'll lead it off, thank you.

CHAIRMAN BALLINGER: Thank you.

MR. WHITE: So, I'm Bernie White, senior project manager in the Division of Fuel Management, along with Jonathan Marcano, Brian Wagner, and Tim McCartin, supported by others here, Matt Humberstone for example --

CHAIRMAN BALLINGER: You've got to turn on your mic.

MR. WHITE: I still need to turn it on, I apologize. So, let me start over, I'm Bernie White, Division of Fuel Management. It will be primarily Jonathan Marcano and I doing the presentation today, we've got others to respond to questions, Brian Wagner, Tim McCartin, Matt Humberstone, and a number of people online to support us.

Unfortunately, I think this is going to seem like a little bit of a herky-jerky presentation, because A, we're limited in time, and B, a lot of this stuff already covered in response to questions. So, I'll see what I can do about skipping over the stuff that I've already covered when it comes to questions. So, what are you going to hear from the NRC?

First is that we believe the transportation regulatory framework is adequate for covering transportable micro-reactors. There's been a lot said today about Project Pele, and the fact that it is a military application. We didn't look at the framework per se as being for solely a military application. We looked at it as would it cover Pele, sure, would it cover other reactor vendors if they chose to use it?

So, we looked at it from a little bit higher level in that respect. And then we also looked at what in the framework will the NRC expect to see in a package application in more fulsome detail that in it all says it may have neglected. For example I talked about things that, the risk criteria were below the threshold for which you have to determine the dose.

We don't believe that, we think we'd want to see dose for every accident no matter what it is, no matter how low the consequence. And they talked a lot about doses that they indicated they neglected. For example, submersion in a cloud dose from the Q system because it's outside. The Q system uses submersion in a cloud, or indoor releases when you're unloading a package.

However, you know, it's potential the package could go through a tunnel, one never knows. So, we would expect to see a lot of justification on that, so that's kind of how we looked at it. Between NRC and DOE there's been extensive engagements over the past few years on Project Pele. We'll talk a little bit about our review of the risk informed methodology, and what we saw at a fairly high level in terms of NRC comments.

And then next steps in development of potential package application that we expect to get. And Dr. Waksman said that it isn't going to go off site, and so we'd be looking to do a safety review on the package application, probably not approve it for transport for that very reason. So, NRC and DOT co-regulate radioactive material, there's a memorandum of understanding between the two agencies which delineate our responsibility, covers a wide variety of topics.

Including safety standards, package reviews, inspection, enforcement, accidents and incidents. The MOU delineates each agency's responsibility of transportation. DOT regulates all hazardous material in transportation, of which class seven, or radioactive is just one of the nine hazard classes. Meaning DOT also regulates all modes of transport.

Which means that not only DOT has regulations on how hazardous material is packaged, but how that package is carried on a conveyance, in this instance on a truck, a heavy haul truck. They also do rail and air. DOT is the U.S. competent authority for transport, which means that DOT represents the U.S. at the International Atomic Energy Agency under the Transportation Standards Safety Committee, also known as TRANSSC.

As the U.S. competent authority, DOT issues certificates of competent authority for NRC approved packages for import, export, and transshipments. Whereas NRC package approvals are for domestic transport only. Also in its role as the competent authority, the DOT issues certificates for packages approved by foreign competent authorities, that's known as revalidations.

DOT sets safety standards for a variety of radioactive material, including type A packages that do not include fissile material, low specific activity, and surface contaminated objects. DOT sets standards for external radiation fields around packages, and labeling and marking of packages. DOT also authorizes shipment of NRC approved packages.

And so, why am I going over all this? Because how NRC approves a package can impact whether DOT has roles in that approval. If we issue a standard package approval, that's automatically authorized under DOT rules. If somebody were to come in and use this framework and request exemptions, they would need an NRC approval and a DOT special permit for that shipment.

The NRC is responsible for setting safety standards for packages and transportation, and issuing certificates for type B and fissile material packages. I say certificates a lot, I really mean package approvals, certificates is how we do business 99.9 percent of the time, but there are other things that we can do, such as letter authorizations, which modifies a certificate in which the package meets Part 71.

There's also alternative approvals which I'll talk about later, up to and including exemptions. Fissile material packages could have a type A or type B quantity of radioactive material. A type A fissile package is not the same as a type A package, because of the fissile nature of the package. Type A packages are not subject to the accident criteria, whereas fissile material packages are.

And that's why we talk about the Q system, and what it does for setting the limits in a type A package, it limits that in the event of an accident no person can receive more than five rem based upon the dose calculations used in the Q system. And we're going to talk about the Q system a bit, but the way we look at it is they use the dose pathways from the Q system, and how some of those calculations were done, and PNNL touched on that earlier.

So, going back to the DOT package standards noting that a type -- sorry. So, in addition as requested by the Department of Transportation, the NRC performs package reviews, and recommends whether DOT should revalidate foreign approved packages. So, we kind of act as a contractor to DOT.

They send us an application that has been approved by a foreign competent authority for which one wants import, export, or transshipment through the United States, and we will recommend whether DOT should issue a certificate for that. So, I won't belabor the point here, we've talked a lot about normal conditions of transport, hypothetical accident conditions.

These are the tests that are done on packages that NRC approved. Normal conditions of transport are intended to what a package might experience during transport. Hypothetic lacks in conditions on the other hand are not designed to be any specific accident, but designed such that if a package can meet the dose rate and containment criteria, which I'll show in the next slide, criticality safety, a package that is in an actual accident would protect the public health and safety.

Package performance criteria. So, I talked a little bit about a lot of these earlier, these are the criteria that we expect packages to meet during normal package approval, we do a normal package approval. There's criticality safety, a single package, an array of packages, think array of packages, Pele really, but we have a lot of packages, fuel assembly packages, uranium hexafluoride, things like that that are shipped in arrays.

They might be small, they could be large, there used to be a significant number of pellet and powder shipments that were 55 gallon drums shipped in quite large arrays. So, we do array analyses for that. There's three single package analyses for criticality safety, one is a non-mechanistically flooded package. So, as the package is prepared for shipment, when you put water in the maximum reactive credible extent, and evaluate the K effective.

Along with after normal conditions of transport and hypothetical accident conditions. And then for array of packages, an applicant has to look at 2N array, or normal conditions of transport, 5N array for hypothetical accident conditions where N is the number that it chooses, the applicant chooses to show that it's subcritical.

So, if the applicant chooses five, for example, they'd have to look at 25 packages for normal conditions transport, 10 packages for hypothetical accident conditions. And that value of N is used to calculate the maximum amount of passages that can be loaded onto a conveyance. So, that's why we go with that standard number, it's a good barrier.

Spent fuel packages may have a criticality safety index of 100, which means that you can only ship one package on a conveyance. For dose rates, there are different dose rates depending upon the package. All packages have to meet the normal conditions dose rate in 71.47, or the DOT version in 49 CFR 173.441. And then if you have a type B package there are additional dose rates you have to meet.

For normal conditions of transport, there must be no significant increase in the dose rate after those tests. Typically IEA guidance has about a 20 percent increase in dose rate being significant. For after hypothetical accident conditions the dose rate is one R per hour around a package. That's been found by the international community to be protective of public health and safety.

Containment criteria, I talked a little bit about those earlier, ten to the minus six A2, and A2 per week for normal and accident conditions respectively. We've already talked a lot about what Project Pele is, I will skip that in the interest of time. I think we've talked a little bit about -- sorry, I missed a slide.

So, levels of regulatory engagement. I won't cover a lot here, but I will say that we've been following Pele in my division, the Division of Fuel Management for a couple of years now, we're acting as a regulator for package approval. The Office of Nuclear Reactor Regulation has a role in Project Pele, and it is to provide DOD and DOE with accurate current information on the prototype such as reactor design, siting, construction, fuel selection and operations, things it oversees in the reactor side of the house.

Skip most of that because we've already covered it. So, why a risk informed methodology, in the event that the Pele package or a transportable micro-reactor can't meet any of those criteria I discussed after a hypothetical accident conditions. The risk informed methodology is not applicable to normal conditions of transport as defined by SCO and

PNNL.

And we would not expect to see that as well. I talked a little bit about alternate test criteria and exemptions earlier, so I will skip that in the interest of time. And I'll turn it over to Jonathan to talk about the risk methodology.

MR. MARCANO: Thanks, Bernie. Good morning, can you hear me? It's Jonathan Marcano, NRC, NMSS. So, we will now transition into the technical content, as well as the staff review of the methodology. As Bernie described on the previous slide why the methodology serves as a basis for the regulatory pathway through exemptions, the next question is what are some of the technical challenges in pursuing this pathway, we have seen some questions around that.

So, one of those challenges is that the risk assessment for the transportable micro-reactor is a first of the kind, and as it might be -- it has been pointed out there are some reports assessing the risk associated with spent nuclear fuel transportation for generic, and NRC 35 casks. Those have been leveraged by PNNL and the staff, but this is the first time a methodology is developed to determine accidents and potential consequences to members of the public and workers for a transportable micro-reactor.

So, we'll be covering more details in the next few slides. So, consistent with the NRC's risk informed and performance based concepts, the proposed methodology serves as a systematic method for addressing the risk triplet. As it relates to the performance of the system, the understand likely outcomes, sensitivities, areas of importance, system interactions, and areas of uncertainty.

Therefore, the staff review of the methodology focuses on that systematic process to evaluate the risk associated with the transportation of the micro-reactor, identify important scenarios that drive the risk, inform the design of components, and identify the need for compensatory measures. The staff has previous experience, as it has been pointed out, applying risk informed approaches to informed exemptions from regulatory requirements for a package with similar challenges.

During its approval, the Trojan Reactor Vessel package in October of 1998, as part of that approval the NRC granted two exemptions to deviate from performing the drop in the most damaging orientation of the package, as the probability of accidents damaging the package beyond that evaluated was less than one in a million.

Other additional considerations by the NRC staff as part of this review of the methodology for exemptions includes the limited number of shipments. In this case, one single shipment per year, two total over several years, and that the package is expected to meet normal conditions of transport, or NCT as it had been mentioned by Bernie, and some hypothetical accident conditions or criterions.

Next slide, Bernie. So, the purpose of this slide is to introduce the major elements of the methodology as proposed by PNNL. We will be covering the risk evaluation guidelines in the next slide, and some of the elements presented here will also be covered during the next slide. As it has been presented, the first step in the methodology discusses the development of proposed risk evaluation guidelines in the form of frequency consequence targets to evaluate the risk assessment results from the transportation package.

The methodology then presents key elements of the probabilistic risk assessment method, PRA for short, such as those listed in this slide, and you have seen a presentation by PNNL. Therefore, the NRC review focused on ensuring that the methodology described in enough details how the risk informed framework will be used to get an understanding on how key elements such as sensitivity analysis will be treated, and how we will consider approaches for defense in depth and safety margins. Next slide. Yes?

MEMBER REMPE: I don't know if you were around earlier when I brought up about the identification of safety functions, and again, Bernie has said you're looking at this for a higher level. I look at your evaluation, it just says hey, they identified the safety functions in 5.2, and if I look at 5.2, and what they presented today, again, they talked about the two higher levels, shielding, and contain radiation, and a couple of things that might challenge that, criticality, or passive heat removal.

But it seems to me since this is going to be an evaluation that could be used for other concepts and designs, it would behoove you to elaborate a bit more that maybe some other critical safety functions that could challenge those primary two safety functions would be a good modification to your draft evaluation. Is that something that you might agree to?

MR. WHITE: Sure.

MEMBER REMPE: You might.

MR. WHITE: Yeah, so let me explain. So, we looked at the methodology as being, I would call it a precursor to a package application, okay? The package application would look at all the things, or most of the things you identified earlier, for example chemical interactions is one of the things. We look at that as a matter of routine practice for our package applications.

We didn't think it needed to be put in here because that's what we always look at for every single package. What is different about how we would evaluate a transportable micro-reactor from a standard package is how we looked at the methodology.

MEMBER REMPE: But considering there's a lot of concepts, a lot of new design developers, I think a couple sentences, you can do it in one, would be prudent. Because people will pick up this document and use it in the future. And it's something that -- again, you look at the regulatory, the reactor side in our regulations, the critical safety functions vary, and I just would like to start seeing more consistency. Thank you.

MR. McCARTIN: Bernie, could I just add one thing? You do raise a very good point, and what we're trying to do in the approval is to be very clear that we're approving the methodology, the approach, we see the steps, but the details, and that's -- there's this fine line, what's detail, and what's part of the methodology?

I think being clear that there's things that this is a first of a kind, what kind of challenges you might see, we are going to look for a justification of the kinds of things you've included, and why, kinds of things you've excluded, and why. And so I think we will take what you said to heart, and look at how we've written this to make sure we clearly identify.

Because there is this, we don't want to leave on this understanding that gee, we thought you approved, for example, there's a lot of discussion about the frequency for accidents. You've got to -- whatever you come up with has to be supportable, defendable, and give us the information. And the demonstration used a lot of different things to help us see how the approach would be used.

But what's approach, and what's demonstration? There are some things that are approached for us, and clear, but maybe it isn't as clear to others. However we approve it, we want to be very clear as to what's needed in the supporting information, and that's what I take from your comment.

MEMBER REMPE: Thank you.

CHAIRMAN BALLINGER: I may have missed it, but did you supply your name for the court reporter?

MR. McCARTIN: I'm sorry, Tim McCartin, NRC staff, I apologize.

CHAIRMAN BALLINGER: Thank you.

MR. MARCANO: We can move to the next slide. So, on the previous slides, Bernie described some of the prescriptive requirements for testing, and the specified acceptance criteria within 10 CFR Part 71. The regulation as written ensures safety by requiring conservative estimates on the damage to a cask, ensuring robust performance in an accident, and requiring conservative numbers on the radiation emitted from the casks during transportation.

Therefore Part 71 does not include quantitative targets, IE likelihood, dose thresholds for approval of transportation packages. With the assumption that the package may not meet all the deterministic requirements and acceptance criteria after a hypothetical accident, a HAC, the methodology proposed a set of risk evaluation guidelines for use in determining safety or the risk acceptability from shipment.

The guidance considered the frequency and consequences by defining pairs of likelihood dose thresholds from the potential exposure to radioactive materials during postulated severe transportation accidents. The likelihood is defined as accident frequency, and we've had many discussions about that, and the consequences are defined as total effective dose equivalent, or TEDE.

The pairs of likelihood dose thresholds are defined for a worker involved in the transportation of the package, and a member of the public located close to or involved in the accident. The member of the public is defined to be the maximally exposed off site individual.

MEMBER ROBERTS: I asked a question earlier to PNNL about the qualitative safety goals, and the one of societal risk, and the implication in transportation when you're shipping this package through or around Denver, you've got a risk profile than you would in the middle of the desert. Some of your previous work had person rem, or person sievert metrics that were in there that were used to try to judge.

I didn't see any of that in the PNNL

report, or in your draft safety evaluation. If you could comment on the societal risk, and how that's being applied through the whole.

MR. WAGNER: Yeah, we talked about -- sorry, this is Brian Wagner, NRC. We've talked about that a little bit internally. I think to some extent that's covered in environmental reviews, although that's not my area of expertise. To a larger degree, we expect that would be covered by the way the dose calculations are done. They're limiting the dose to the maximally exposed off site individual.

And by doing so you're going to necessarily to some degree limit the societal risk. That's not always fully true in some circumstance when you have larger source terms, or taking protective actions which might limit the dose your maximally exposed individuals are getting more than they're limiting the silo dose.

But in this case, you would kind of expect that the overall inventory and source term are relatively modest compared to a large reactor for example. Such that the people right around the accident are really the ones that are going to be most exposed, and that people at any kind of significant distance are probably not going to be getting a whole lot of dose. And that's what we've seen in past transportation PRAs.

MEMBER ROBERTS: The 2008 RIDM document, and I'm not sure that the part of this is necessarily always true, if you had your highest risk of flying accident for example, in the middle of a city, then maybe that would be a different story than if the same -- the integrated risk had that -- integrated probability had that flying potential in the middle of nowhere.

Just something to look at. At the very least it seems like there are going to be some discussions of this qualitative goal, and how that's tested in the context of transportation. But that is different than a reactor site where you've got other environmental reviews, and other regulations to limit the affected population.

Whereas here you're kind of putting that protection in a package, and in the analysis you use, and not so much in the affected population. But I see what you're saying, and it may very well be that when you look at the individual risk metrics it gets you satisfactory coverage to societal risk. Or it may drive us to desire some additional margin somewhere. Thank you.

MEMBER BIER: I would also just reemphasize my point from earlier this morning, that I'm not sure it makes sense to look at the pairs of likelihood and dose individually rather than integrating them over the entire trip or whatever, the entire range of possible scenarios, and taking an overall perspective. That's just me.

MR. MARCANO: So, we've talked about the references used in the development of the evaluation guidelines, and how the methodology aims to tie those proposed guidelines to the QHGs defined in the RIDM report. So, the staff review focused on ensuring the risk targets are consistent with NRC risk informed approaches to be used as objective means of comparing the likelihood and consequences of the scenario.

Therefore the staff review was aimed at confirming that the methodology proposed a conservative approach to calculating risk targets, to demonstrate the public health and safety is protected during transportation of the micro-reactor. Therefore the staff took into consideration the totality of all the references used for the delineation of the guidelines, such as DOE guidance, and guidance in NUREG-1520 developed for fuel cycle facilities, as well as the IAEA Q system.

Additionally, based on our review, the staff agrees that the approach is similar to risk informed approaches previously endorsed by the NRC to support the licensing of advanced reactors in Reg Guide 1.233, which endorses the NEI 18-04. Next slide. And PNNL covered this, this is mostly for illustrative purposes to show the frequency consequence plot for the members of the public.

The next slide will cover the frequency consequence plot for the worker, and we don't plan to go through each of the anchor points. We do have a slide in the reference, slide 28, that includes the anchor points that were presented by PNNL. I do want to note that the proposed targets in the methodology are slightly more conservative than those previously endorsed by the NRC in Reg Guide 1.233.

We can move to the next slide. So, now we're moving from the risk evaluation guidelines into the key elements of the PRA methodology. As part of the first elements within the PRA, the methodology evaluates hazardous conditions that may exist during transport to formulate realistic scenarios. It consists of three elements. Characterization of the primary hazard, the radiological material inventory.

Identification of the micro-reactor safety function designed to prevent or mitigate accident scenarios associated with the radiological material inventory. Identification of accident scenarios and their likelihood. The results are compared to NUREG-2125, which is a spent fuel transportation risk assessment to review the comprehensiveness of the process.

The methodology later identifies representative and bounding accidents that may result in the release of radioactive material to the environment, or indirect radiation exposure to workers or the public. A total of 32 representative events were identified. The bounding representative accidents, which were grouping to 32 representative events, which were then grouped into 13 accident scenarios referred to as bounding representative accidents for detailed analysis.

So, the staff reviewed these areas, and agreed that the methodology appears to provide a systematic approach to identify accident sequences that drive the risk.

MEMBER REMPE: I'm less certain on this one about my comments about it doesn't make sense to multiply the fraction of the path by the whole distance to estimate the frequency. But actually what

Member Bier said is suddenly driving home, that if you did what she's suggesting, and consider the frequency, and the consequences every point along the path, that you'd have a more accurate representation.

But what they've done, and again, you're looking to approve the methodology, not the specific numbers, and that I would call as part of the methodology, where they've divided this, and they've made that frequency lower because it's only a small fraction of the whole path. Is that what you guys always do in these types of evaluations, or are you giving them a very low frequency benefit? I'm not sure if I'm communicating what I'm trying to say very well.

MR. WHITE: So, being the non-PRA person, I'll start by saying we don't typically do these things in analysis. Because we don't have to, because the package meets Part 71, when you meet Part 71, you meet the dose containment criteria, you're protecting public health and safety, so we don't typically look at that.

We would look at, along the route, the possibility of accidents, and calculate collective dose to people along the accident. But that's really to show that the regulations in Part 71 are protective of the public health and safety, and by meeting the regulations, the package is protective of the public health and safety.

MEMBER REMPE: So, I guess look carefully, at 182, look at that frequency and how they've estimated it. Because to me it doesn't sound right. If you've done what Vicki is suggesting, yeah, it would probably not do it, but it just doesn't seem right.

MR. WHITE: So, let me start by saying sorry, Bernie White, NRC staff. And this is where I turn to my colleagues to see if they have any comments on that, being the non-PRA person.

MR. McCARTIN: Yes, Tim McCartin. I think I agree completely. We need to go back, and we know what was done, but what you're talking to is a very important aspect of what -- and we want to be very careful in explaining what we're approving and why. And people can look at different things, and well, that's part of the methodology versus part of the demonstration.

And the particular point you're talking to is there's a fine line there, I think. But I think I do, right now, I would agree with you, that actually is part of the methodology, and we need to look at that, and articulate. Right now I'm not going to try to come up with it, we want to --

MEMBER REMPE: That's fine, that's the answer that I wanted to hear, just look at it further, because I don't know the answer.

MR. McCARTIN: We want to think a little bit more about that, and we want to be clear in whatever we go forward with.

MEMBER REMPE: Thank you.

MEMBER HALNON: I have one other question, being a non-PRA, very deterministic person. Is it assumed that when you get an accident it becomes non-transportable at that point and just stays stationary?

MR. McCARTIN: No, the easy answer is no, not necessarily. It really depends upon the package, and the type of accident, and the damage to the package, that's really what it comes down to. For example, and I'm probably going to get the year wrong, but I want to say it was in 2021, there was a shipment of uranium hexafluoride came from France to the port of Baltimore, offloaded onto a truck, was driven down 95 going to Westinghouse.

Truck had an accident, car cut in front of it, it hit the car in front of it, the uranium hexafluoride over packs are shipped on a flat rack.

So, it basically looked like a SeaLand container without the walls. So, it's got kind of a back, and then structure, and the racks are strapped onto that, there's four of them.

That flat rack came off the truck, two of the packages came off the flat rack. So, what was done in that instance is they got a crane out there, they took the two packages, they put them back on -- they got a new flat rack, they put all the packages on a new flat rack, shipped it to a local -- I'm not remembering the term, but it's a place, not a truck stop but a place a truck would go to evaluate it.

They looked at the packages, determined whether or not they were transportation worthy, and determined they were based upon the damage to the package, and then they were shipped along the way. So, the answer is not necessarily.

MEMBER HALNON: Okay, so this methodology, we talked about the recovery earlier, that's more to come, because I see that's the problem. I mean, transporting a great cask that doesn't have any accidents is perfect, it's afterwards that I'm worried about.

MR. McCARTIN: Right, and recovery is probably -- not probably, it is mode dependent, it is reactor dependent. We didn't look at that in great detail here because of that very fact that it could be reactor and accident dependent.

MEMBER HALNON: Okay, and I understand that, that to me is the safety issue, not transporting a perfectly good cask on a sunny road. Or you can ask folks in my home state, East Palestine are still dealing with the emotional aspects of having a train go through. So, anyway, to me, if I ask you any questions about recovery just say hey, we talked about that already, we got it.

MEMBER BIER: But that's a really interesting point, Greg, because when you said does it become non-transportable, and the answer is not necessarily, almost no matter how bad the damage is, you're not going to leave it in the creek bed or whatever, you're going to transport it somewhere in a much worse condition than you would hope to transport it. So, might be worth having a follow on analysis that looks at that.

MR. WAGNER: Brian Wagner, NRC, I'll just note that recovery operations are typically not covered in PRA, we consider the consequences in the relatively immediate aftermath. The entire operation Bernie just described of how you're recovering, or what you're doing after, that's really nothing that is, I think ever covered in PRAs, for better or worse.

MEMBER HALNON: I would just note that when I was an operator, I did very simulation of normal operation. It was always recovery operations what I was trained on. And that was where we focused, because that was the highest risk to the public. So, to me, the highest risk to the public is the recovery and operation, just wanted to say that.

MR. WHITE: So, now we'll walk through the accident sequence analysis as we looked at it. The consequence analysis has several steps, one of which includes accident sequence analysis. For a spent fuel transportation package with its passive features, this typically includes forming an engineering evaluation of the damage to the package, which would include the package as it's shipped, which would include looking at chemical reactions and things like that, that may degrade the package.

While the methodologies and approach to determine risk for transport of a transportable micro-reactor, the actual analysis in this methodology don't represent damage to the package. It was based on engineering judgment by PNNL, and so we didn't review that specific detail. I'm trying to skip the things

I've already covered in some of my questions, so bear with me just a little bit.

NRC would expect that the package application would either provide an engineering assessment of the reactor for the accidents that it's evaluated, and include damage to the package and potential releases along the route with appropriate justification. The package applicants should evaluate the radionuclide inventory that it expects to have at the time of shipment.

In the methodology, PNNL will assume that the reactor was operated to its full life expectancy, and then determine radionuclide quantities for various cooling times from right at shut down to up to three years. And as you saw from PNNL, they did sensitivity analysis on some of those to determine that it can have a large effect. It's possible that reactors could be operated for a short period of time and then shipped, or a long period of time and shipped.

So, we would expect the application to evaluate whatever it expects to be the radionuclide inventory in the package at the time of shipment. While PNNL provided a two phase screening of the radionuclides, one in total activity, and the other one in A2 value, while the NRC has accepted screening based on A2, NRC's acceptance has been based on the package releasing no more than an A2 in an accident after hypothetical accident conditions.

If the package were to release more than an A2, NRC would expect that one of the sensitivity analyses that would be performed would be on the neglected radioisotopes. Kind of the A2 screening is based on a limited quantity release in A2. If you release a million curies for example, that A2 screening may not be appropriate.

PNNL developed primary release, meaning radio nuclides that came out of the core, migrated to other areas, and were released in the reactor module. They neglected secondary releases such as activated components of the reactor itself. PNNL deemed those to be of small, low significance. NRC would expect the applicant to either include them or justify the fact that they are a low significance.

DR. SCHULTZ: Bernie, this is Steve Schultz. Just focusing on the material release, both going and coming back from its operation. One of the things that was suggested both in the PNNL report, and also in your evaluation was mechanical testing associated with the TRISO fuel, that additional information related to mechanical impact testing would be useful. The one bounding representative accident that is outside the bounds is high impact.

So, is this testing going to be recommended, is it planned, where does that stand at this point?

MR. WHITE: So, I don't want to speak for SCO, but they had to develop a testing program for the TRISO fuel, which includes mechanical impacts. We've seen a draft plan of that.

DR. SCHULTZ: Do you know what the schedule for that is?

MR. WHITE: I do not.

DR. SCHULTZ: We can find out, but that's part of your evaluation?

MR. WHITE: Right, and in looking at a lot of the work that's been done on TRISO, most of it is in reactor testing at temperature. For us, temperatures in a fire accident aren't that high. We'd be looking more at what's the mechanical impact in an accident.

MR. WAKSMAN: I'm not going to be able to answer your question precisely because some of the testing that we're doing is classified, and some of it isn't, and I don't remember exactly the boundaries, so I don't want to get myself in trouble. But I can tell you that we are planning to do some physical testing of TRISO over the next couple of years.

And we've been coordinating that with the NRC team, so the NRC folks are tracking. We've had at least one classified meeting with them to walk them through what we are planning to do. And part of the input we were taking is there particular data that will be helpful to the NRC, that maybe we could collect, or might not collect, or just to try to coordinate as well as we could.

DR. SCHULTZ: That's the information I wanted on the record, so that's fine, thank you.

MR. WHITE: A lot of discussions about the dose pathways, I'll skip most of this in lieu of time, since we're at about 11:44 already. But one thing I will say is that there are a number of dose pathways that were neglected by PNNL, we would expect that the applicant would justify those, especially if it's a large release. Some of those may not be insignificant dose pathways.

PNNL also indicated the neutron dose they expect to be insignificant. NRC has found in some of its package reviews, especially after hypothetical accident conditions, that where you have a small amount of low Z material, neutron dose can be not appreciable like the same as a gamma dose, but not neglectable either. And so, we would expect an applicant to evaluate neutron dose from the accident.

These are dose pathways from the Q system, I won't go over any of that. So, if you're estimating the consequences, the methodology provides a summary of the radiological risk for each of the bounding accidents, and compares the likelihood in dose to the risk evaluation guidelines. The methodology then describes a process to evaluate sensitivity and sources of uncertainty.

We would expect a much more fulsome discussion of sensitivity on certainty analysis, and defense in depth in the package application, which would be reactor dependent. Staff review agrees that the methodology provides an adequate process to identify, characterize, and understanding the impacts of modeling assumptions, model inputs, and key sources of uncertainty.

Additionally, the methodology articulates the defense in depth approach for Project Pele based on the multiple layers to prevent release of radiation, passive nature of the design, and compensatory measures taken to reduce risk to worker and public. For example, the one point that PNNL showed that was above the limits, if you sit, decay it a couple of years, you're below the limits.

Other things as not shipping in bad weather, looking at weather forecast days, weeks out. Ensuring that if you're going to ship, it's not in high traffic volumes, likely to have more accidents, and things like that. So, there's a number of compensatory measures that can be taken to minimize the probability of an accident.

And moving along, I'll just hit the next steps. So, where are we for the next steps? We're scheduled to have an ACRS full Committee on December 6th, we have an information commission paper that is in the process of going through concurrence that we hope to issue by the end of January. Attached to that would be the NRC management reviewed draft methodology evaluation, and I know it was mentioned earlier, we don't call it a safety evaluation.

And we don't do that because we don't compare it to anything in NRC regulations for acceptance criteria, it's a higher level approval. That would be an attachment to that information commission paper, and then if all goes as planned, we would look to endorse the framework in the February time frame after issuance of that commission paper.

NAC has indicated that they'd like to have the methodology approved by the end of January, or thereabouts, because it plans on starting its PRA at about that time. We expect to have pre-application engagement with NAC, so I said earlier that SCO contract with BWXT to design, build, and operate the reactor, BWXT contracted with NRC International to develop a package application for us to review.

We expect pre-application engagement with them in the first quarter of 2024, and NAC has indicated that we should expect an application for this by the end of calendar year '24. A few references, and there ends our quick overview.

CHAIRMAN BALLINGER: Okay, I guess we should get public comments first. So, if there are members of the public that would like to make a comment, please state your name, and if necessary, your organization, and make your comment. Hearing none, thank you very much. We need to have a little bit more clarity. Again, we had scheduled a full Committee meeting as a placeholder, not knowing what was going to happen to go forward.

That would only be the case if we were to write a letter, in which case, as it now stands, and it might change in 30 seconds, we were not planning on writing a letter, and we got information that said you don't necessarily need, want a letter. But I'm just one person. So, now we need to have some discussion around the table, and amongst our members online on what their opinions are, what we should do with respect to a path forward.

So, I'm not sure where to start, how about Tom? How about who?

MEMBER REMPE: The staff has indicated they're receptive to some suggestions for change, and what would be your time line for implementing those changes, can you do something by the first week of December?

MR. WHITE: That's a loaded question. Can we do something, absolutely. Get it reviewed by management and out the door in a publicly available form, not clear about that to be honest with you, given the fact that next week is Thanksgiving, most are planning on taking off a good bit for Thanksgiving.

CHAIRMAN BALLINGER: I'd add that there are other options. One of them being that we would write up a summary, if you will, of this meeting, that would include suggestions, if you will, not in a formal letter, that would be incorporated and discussed in our policy and procedures, it would become part of the record, which you would have access to. So, that's another venue which is probably quicker.

MR. WHITE: Okay.

MEMBER REMPE: So, one thing that could occur is you could still present at the full Committee meeting with what your planned changes are, and then again, it's at least on the transcript in the record, and would that help with your time frames rather than having to have something documented, that with all due respect, if you say well, they told us they were going to, and we don't have any sort of formal interaction.

And we say well, we heard during the subcommittee meeting they were receptive to some changes, which may or may not happen, that one leaves me a little less comfortable than at least if we had the meeting and it was documented in the summary report, and whether it's a letter, and we emphasize three or four things, or it's in the summary report I'm not so particular about.

But I think we need some follow up, just because this is something where other people will be using this framework.

MEMBER BIER: Yeah, if I can comment out

of turn, Vicki Bier --

CHAIRMAN BALLINGER: --- no turns.

MEMBER BIER: Well, okay, you were trying to have turns, but my sense is that it is probably not necessary for us to come back kind of for the purposes of the Pele analysis and report. But that it might be worth writing a letter focused on which aspects of this we think do provide precedent for future analyses, and which aspects would require more work before being ready to go forward.

And that gets you guys out of the trap of having to do a quick turnaround change on something that might not be so quick. But still gets our concerns and opinions out for the future, so that's my vote.

MEMBER ROBERTS: This is Tom Roberts. I think my two primary issues, neither which was fully resolved today, nor did I necessarily expect them to, one is almost a philosophical question on how the qualitative safety goals play into societal risk of transportation, and I don't think that's going to get resolved in two or three weeks, that's just something --

CHAIRMAN BALLINGER: Yeah, that's almost biblical.

MEMBER ROBERTS: Yeah, almost. And that's just something that probably ends up with some sort of a coherent write up of how the existing individual goals meet the objective of societal risk. So, that's one I don't think we would really need to have a letter for. So, the second one is the -- we call it uncertainties, or sort of cliff edge effects, or that type of thing.

But that was, I didn't think clear in the PNNL report or the draft SC. And I recognize for example the thought process for criticality is that the probability is probably not low enough to really screen out criticality, so in real life the package would be redesigned to preclude criticality using a more deterministic approach, and I didn't get that from either the panel report, or the SE -- not SE, the non-SE in the evaluation.

That's something that you would be very skeptical about, and expect some sort of an assessment of either the consequence, or the degree of uncertainty, and the potential for cliff edge effects, whatever you want to call it. And I don't know if we need to have a formal letter to communicate that, but it's just something that kind of goes in Joy's and Vicki's statements, something to think about maybe making clear in the evaluation.

You have some of that in there, like you expect to see dose evaluations for events that are screened out, but something in more clear documents, criticality being almost it's on a category of risk that you would expect either more assessment, or deterministically screening it out.

CHAIRMAN BALLINGER: We have a number of members that can't participate in a deliberation, so I want to see if Greg or Charlie has something.

MEMBER HALNON: Yeah, my only aspect on all this is to make sure that -- and I was just looking through the SER to see if I could find it, just a clear boundary of what is this, and what is it not? It doesn't cover the recovery actions, which to me is the highest risk. As I had mentioned, it does cover Pele project to a certain extent, it doesn't cover zoning.

As long as it's clear in the SER, and I have to go back and read it again to see if that mind set is in there, or we write a letter saying this is what we see it is, and this is what we see it's not kind of goes along with a previous comment, I think it was Vicki, that said it's got to be what are the next steps type of thing, if you wanted to apply this somewhere else, what would we have to do?

CHAIRMAN BALLINGER: I think we ought to be -- I agree, but we should remember that they had a statement of work to do certain things, and what you're talking about is something that's important, but was not part of their statement of work.

MEMBER HALNON: And what they worked on is what they worked on, but what people perceive it as being, and what it might get used for in the future is different. And the SER does a good job, in my mind, of going through and looking at their work, the statement of work. But it doesn't, in my mind, bring out as this is what it's not meant to be as a public -- as a step going forward.

But it certainly is a methodology stepping stone to those, but it's not a proven --

CHAIRMAN BALLINGER: It may be, let me -- my level of ambivalence on a scale of one to ten is now up to like eight. So, it may be that any summary that we would write, if we were to write a summary, that's the place where we could say okay, this, and that, but in the long term you need to consider the following areas a little bit more carefully.

Not necessarily modify the PNNL report, but it's comments to the staff that yeah this was fine. But in the long term a report in issues --

MEMBER HALNON: From my issue, a summary statement of two sentences would satisfy.

CHAIRMAN BALLINGER: Okay.

MEMBER HALNON: So, that would be perfectly adequate, it'd be making it clear this is what we concluded.

MEMBER BROWN: Is it my turn yet? You're asking for -- I'm not just ambivalent, I have a hard time understanding we either write a letter of summary where we try to get consensus in some, whatever words we want to say, it's not officially voted on by the entire Committee, but yet supplied for them is not going to happen in two weeks. That's too hard.

CHAIRMAN BALLINGER: The summary would have to --

MEMBER BROWN: Let me finish, okay?

CHAIRMAN BALLINGER: The summary would happen in PNP, and --

MEMBER BROWN: How you're going to get a consensus summary written, the summary stuff, we're getting carried away with these things. Every time I turn around it seems like we're now having summaries, and we're documenting actions in summaries. If we have something very specifically we want to comment on and provide to them, we ought to do that. If we don't, and it's just a bunch of comments that we monitor observations, that doesn't provide much direction.

Not direction, but suggestions for the staff as to what the Committee really feels over the long haul. I mean, to me, this was a good presentation, I mean the idea of taking a micro-reactor, moving it from the facility to where you want to go use it, good idea. But now once it's out of gas, you've got to take it out and move it back. Well, why not just take the fuel out, leave it in place, and put new fuel in it while it's there, it's just a smaller reactor that you've built some place.

That thought process is not even in it. I don't -- it's not the same stuff that you're doing, just an overall thought process of how the small module, the small really tiny micro-reactor, which has some usefulness would be used. I just don't see how we can come across with a coherent write up that's not formally voted on by the Committee.

The Committee can outvote me, but that's my position on the circumstances. I don't agree with a summary trying to resolve all these little nuances.

CHAIRMAN BALLINGER: Walt, and Matt.

MEMBER KIRCHNER: Well, just in summary, I would say what was presented today, it's a good framework, particularly for Pele, which is more of a national defense application. The implications for widespread use commercially begs a lot of questions about, as I said earlier, proliferation risk, and proliferating risk, nuclear materials, and health and public, the safety.

And I'm just -- a strong footnote, many of you know I looked at this very closely, not as structured as this 40 years ago, and one of the things that we decided early on was we would use TRISO fuel, which takes a lot of design safety considerations off the table, versus other reactor types. So, other reactor types will present many more technical challenges and probably require many more compensatory measures in terms of design like additional control absorbers, and such to prevent criticality accidents.

So, I could go on and on, I'll stop there and just say that -- thanks for the presentations. I think it is a good framework, I think it could be made to work for Pele, but going beyond that, I don't know if it's broad enough at this point, framework for commercial applications. Thank you.

CHAIRMAN BALLINGER: Matt?

MEMBER MARCH-LEUBA: I'll take his place. Yeah, I don't have a very strong opinion one way or the other. I wanted to emphasize Charlie's point, I think he's correct this time, for a change. The summary was designed whenever we have a subcommittee and we don't want to follow up with anything, so we will not be doing a full Committee meeting, we will not be writing a letter.

And the summary summarizes our position that we are in complete agreement with what we saw. In this case, if we have suggestions, the summary is not a good method, or mechanism. And that said, I think we can split the baby in half by saying that it is perfectly okay what we're seeing for Pele about we expect a more detailed implementation with several topics for commercial operations, which is not what the staff is doing now. So, there you go, okay, next.

MEMBER BROWN: The transcript is also available for them to get whatever they -- the comments and suggestions we've had. Those they think are valuable, they can utilize them. If they don't, we can address it in some other circumstance, I'll stop right there.

CHAIRMAN BALLINGER: Matt? He must be gone.

MEMBER REMPE: We're running out of time.

CHAIRMAN BALLINGER: We are out of time.

MEMBER REMPE: So, I think the outcome on this should be that we will have the full Committee meeting presentation. You can talk to Chris about the timing, it should be more succinct. But I think you need to have a draft letter ready, and if we decide to do a summary, it's the same thing as last month, we've got the routine down, and we can decide after that meeting. Is that okay with you, Ron?

CHAIRMAN BALLINGER: Okay with me. I am not a PRA person, so any letter that I would write would probably be closer to a Peanuts cartoon than --

MEMBER REMPE: So, I think that Tom, Greg, Vicki and I should give you some input, and we'll work together if that's okay with you, everyone wants to do that over their Thanksgiving holiday. But we are out of time. I really appreciate your presentation and your effort to make it more succinct. Back to you.

CHAIRMAN BALLINGER: Don't know why I actually ran this meeting, because I didn't. Okay, well, thank you very much. And if you've witnessed the confusion, that's correct. So, thanks again, and we are adjourned.

(Whereupon, the above-entitled matter went off the record at 12:05 p.m.)

Pacific Northwest
NATIONAL LABORATORY

Development and Application of a Risk-Informed Approach for Regulatory Approval for Highway Shipment of a Microreactor

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Advisory Committee on Reactor Safeguards Meeting
November 17, 2023
Washington D.C.

U.S. DEPARTMENT OF ENERGY BATTELLE

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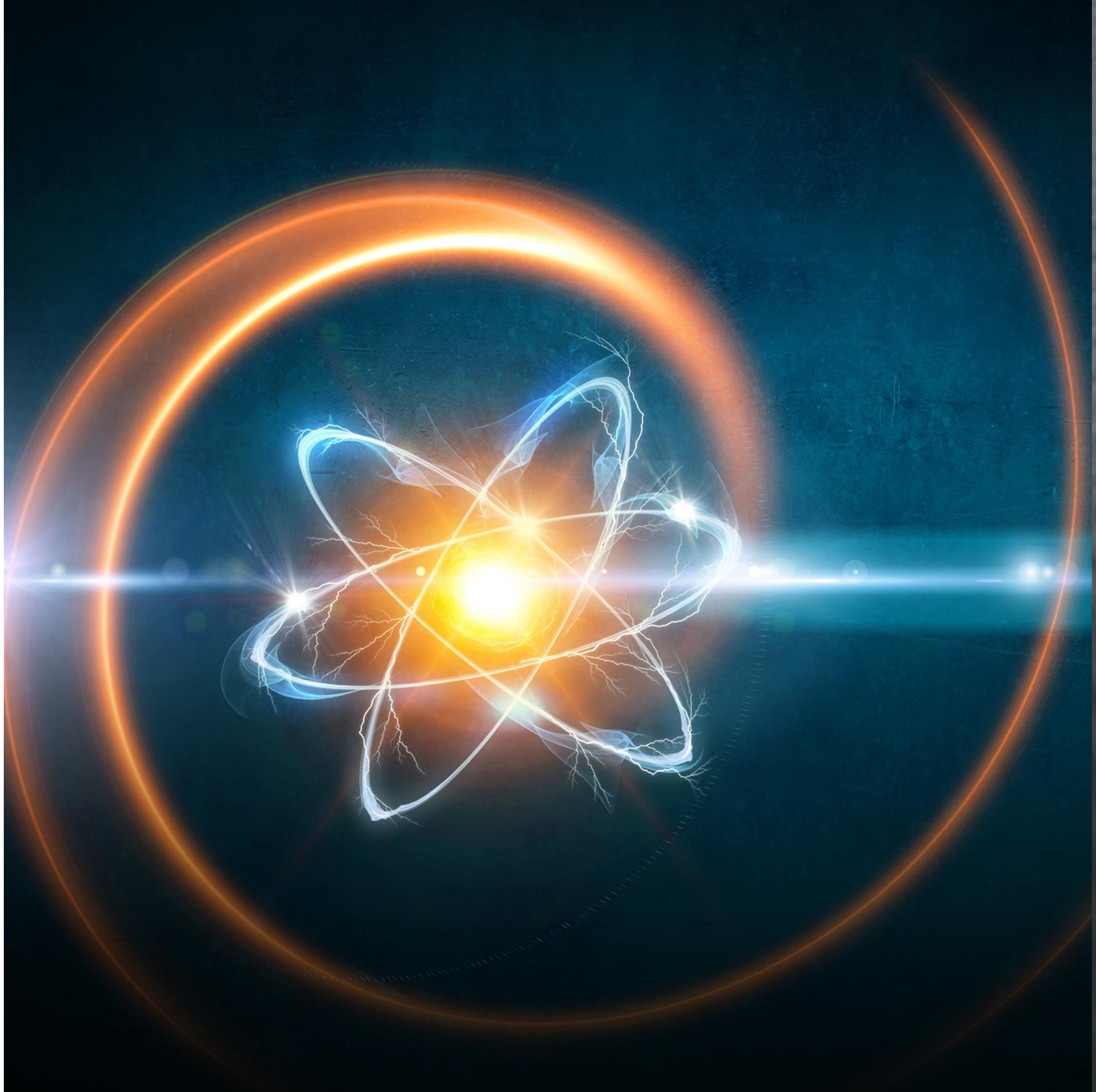


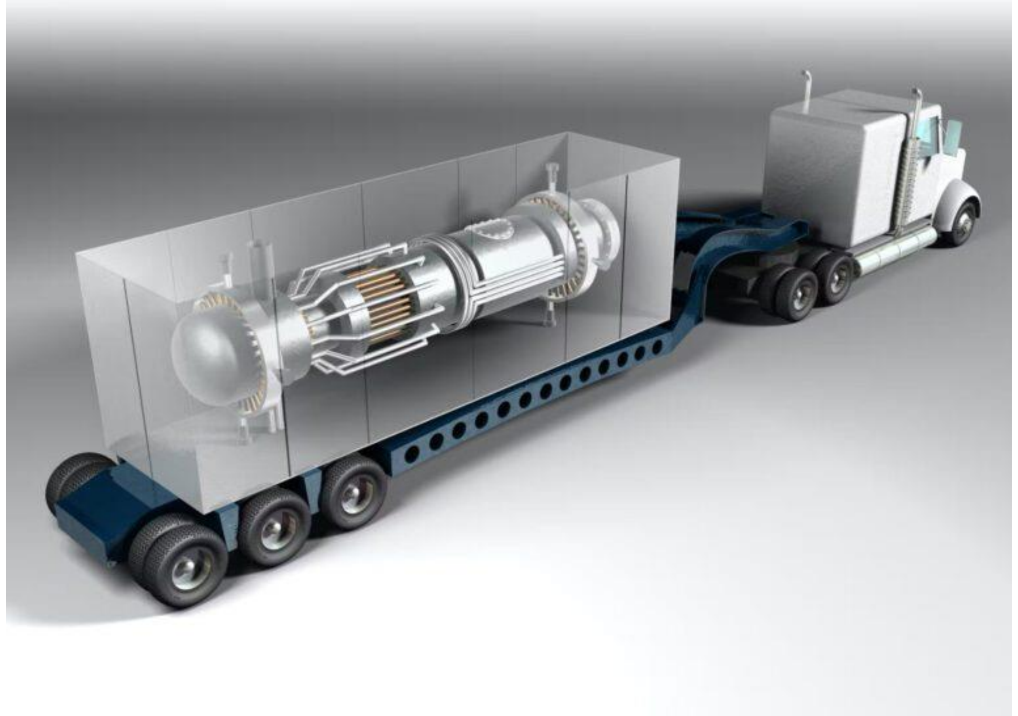
Purpose and Major Elements of Presentation

Purpose: Provide background information on proposed risk-informed regulatory approach for the transportation of a transportable nuclear power plant (TNPP) in support of NRC draft safety evaluation

1. Brief description of the demonstration TNPP
2. Description of the proposed risk-informed regulatory pathway for TNPP transport and why it is needed
3. Development of proposed risk evaluation guidelines
4. Description of quantitative risk assessment process using an integrated assessment process based on probabilistic risk assessment (PRA) methods which includes consideration of defense in depth (DID) and Safety Margin
5. Example results of applying the proposed PRA and risk evaluations guidelines to the demonstration TNPP using PNNL's proposed approach
6. Description of approach to and results of sensitivities studies and uncertainty analyses
7. Insights gained from implemented demonstration of PNNL's proposed approach

Transportable Nuclear Power Plant (TNPP) Package

- Many advanced reactor vendors are developing TNPPs to make higher density energy readily available for:
    - Department of Defense’s (DOD’s) domestic infrastructure resilient to electric grid attack
    - Enabling rapid response during Humanitarian Aid and Disaster Relief (HADR) operations
    - Clean, zero-carbon energy in a variety of austere conditions and off-grid locations
- These TNPP conventions would be factory produced, fueled, acceptance tested, and deployed as sealed units prepared for transport and retrieved for refueling and reapplication



Semi-Tractor and Trailer Carrying Reactor Module

Photo courtesy of News & Technology for Global Energy Industry, April 21, 2022 https://www.powermag.com/green-light-for-project-pele-defense-departments-mobile-nuclear-microreactor-demonstration/

Project Pele used to Demonstrate Risk-Informed Regulatory Pathway

- 1 to 5 MWe, minimum of 3 years of full power operation
- HTGR using HALEU UCO TRISO fuel
- Multiple modules
  - Reactor Module
  - IHX Module
  - Control Module
  - Power Conversion Module
- Reactor Module contains a vast majority of radioactivity at EOL (remainder in IHX Module)
- Each module contained in and integral with separate ISO-compliant CONEX box-like containers

Artist's rendering of BWXT's Project Pele transportable reactor modules arriving for set up and operation. (Image: BWXT)

Photo courtesy of NuclearNewswire, June 9, 2022
https://www.ans.org/news/article-4035/bwxt-wins-project-pele-contract-to-supply-nations-first-microreactor/

Acronyms: MWe – megawatt electric; HTGR – high temperature gas-cooled reactor, HALEU – high-assay low-enriched uranium; UCO – uranium oxycarbide; TRISO – tri-structural isotropic; IHX – intermediate heat exchanger; EOL – end of life; ISO- International Organization for Standardization; CONEX – container express

Need for Risk-Informed Regulatory Approach

- US transportation regulatory requirements contained in 10 CFR Part 71 primarily focus on the definition for thick-wall steel vessel for SNF transportation package
- A TNPP with its irradiated fuel contents prepared as a package for transport could be challenged to meet the entire suite of codified regulatory performance requirements in 10 CFR 71
  - It is anticipated that the TNPP will be capable of being deterministically shown to comply with the Normal Conditions of Transport (NCT) as outlined in 10 CFR 71.71
  - However, it may be challenging to demonstrate that the level of robustness of current proposed TNPP technology can fully meet the dose rate and containment success criteria after Hypothetical Accident Conditions (HAC) tests as outlined in 10 CFR 71.73
    - ✓ E.g., Sequential 30 ft free drop, crush, puncture free drop, 30-minute engulfing hydrocarbon fire, and water immersion tests
- Leverage compensatory measures and defense-in-depth approaches and philosophies to reestablish equivalent safety
- Leverage consideration of TRISO, compact, fuel sleeve, core, and reactor structure related inherent retention and protection boundaries

Basis for Proposed Regulatory Approach

- If Fissile Material or Type B package postulated HAC requirements (10 CFR 71.73) cannot be directly met, then other package approval options are possible:
  - 10 CFR 71.41(c) Alternative Environmental and Test Conditions (10-160B and 8-120B Transportation Casks)
  - 10 CFR 71.41(d) Special Package Authorization (West Valley Melter Package)
  - 10 CFR 71.12 Exemption (Trojan Reactor Vessel)
- Approval of transporting the Trojan Reactor Vessel up the Columbia River and on the Hanford Site was based on compensatory actions as it could not be fully tested.
- Preferred initial pathway identified by PNNL is the Exemption process that allows compensatory actions to protect the basis of exemption if acceptable risk is demonstrated
  - Can apply to more than a single shipment unlike Special Package Authorization
  - Flexibility in deviating from deterministic requirements compared to Alternative Environmental and Test Conditions

Reasoning Behind Selection of this Regulatory Approval Pathway

- Quantitative risk analysis approaches such as Probabilistic Risk Assessment (PRA) are used in risk-informed regulatory approaches for the NRC:
  - PRAs have been conducted since the 1970s for nuclear reactors starting with WASH-1400 and used since the 2000s for risk informed licensing applications.
  - PRA has also been used to assess:
    - ✓ Dry cask storage systems at a nuclear power plants (see NUREG-1864)
    - ✓ Transportation of spent nuclear fuel (SNF), most notably in NUREG/CR-4829, NUREG/CR-6672, and NUREG-2125
- Proposed to NRC as an aid in developing a near-term approval pathway to drive Advanced Factory-Produced TNPP development and deployment
- Bridges the gap between the current regulatory framework (thick-wall steel vessel based) and the level of robustness of current proposed TNPP technology
- Provides buffer time for strategic regulatory considerations and possible rule making to more so accommodate advanced, transportable, microreactor conventions

Risk-Informed Regulatory Approval – Using Exemption Process

- Quantitative Risk Assessment - Demonstration of acceptable risk will require a quantitative assessment given (1) the complexities and uncertainties about package performance and (2) potential risk to public. PRA provides a rigorous quantitative approach
  - Unlike the approval pathways used in the past (e.g., Trojan Reactor Vessel), it is unlikely that all accident scenarios can be screened based on likelihood.
- Risk Evaluation Guidelines - Quantitative risk assessments work best when supported by guidelines about acceptable risk as a key basis for regulatory decisionmaking
- However - risk-informed regulatory guidelines using PRA do not exist for transportation packages like they do for nuclear power plants (NPPs)
- That said – The proposed risk evaluation guidelines are based on the risk-informed decision making (RIDM) guidance in NRC 2008 report for nuclear material and waste applications (ML080720238)
  - This guidance includes proposed quantitative health guidelines developed from the 1986 NRC Safety Policy Statement
  - Challenges remain in its implementation and the approach has not been endorsed for use by NRC as that would be a policy decision

Proposed Risk Acceptance Guidelines 2008 in RIDM Report

NRC-Proposed Qualitative Health Guidelines (QHGs) Based on Interpretation of Safety Policy Statement

Receptor	Acute Fatality	Latent Cancer Fatality (LCF)	Serious Injury (Cancer Illness)
Public	QHG-1 - Public individual risk of acute fatality is negligible if it is less than or equal to 5×10^{-7} fatality per year.	QHG-2 - Public individual risk of a LCF is negligible if it is less than or equal to 2×10^{-6} fatality per year or 4 mrem per year	QHG-3 - Public individual risk of serious injury is negligible if it is less than or equal to 1×10^{-6} injury per year.
Worker	QHG-4 - Worker individual risk of acute fatality is negligible if it is less than or equal to 1×10^{-6} fatality per year.	QHG-5 - Worker individual risk of LCF is negligible if it is less than or equal to 1×10^{-5} fatality per year or 25 mrem per year.	QHG-6 - Worker individual risk of serious injury is negligible if it is less than or equal to 5×10^{-6} injury per year.

- **1986 NRC Safety Goal Policy –** The premise is that risk to people from a nuclear power plant should be very small compared to the sum of other accident risk (e.g., 0.1% prompt fatality)
- **Workers** are not specifically addressed in the Safety Goal Policy, so the 2008 RIDM report proposes that worker risk be small compared to other risk but not as small as for the public who are not trained in radiation protection

Justification for Using Surrogate Measures for QHGs

- As an analog - Levels of NPP PRA include Level I (CDF/LERF), II (release), and III (health effects)
  - However, NPP PRAs (which are mature and well used) are not typically taken to Level III, but rather use the surrogates of CDF and LERF for risk-informed applications, as they are more feasible (see RG 1.200)
- PNNL proposes using surrogates for the QHGs suggested by the 2008 RIDM report by formulating goals in terms of radiological dose and likelihood limits to an individual receptor, which are more feasible to achieve:
  - Reduces calculational burden by eliminating determination of health effects
  - Dose limits can be compared to other federal/international dose limits used in related contexts
  - Determining likelihood and consequence as pairs provides added information for decisionmaking
- PNNL examined the use of dose consequence-likelihood pairs from other applications
  - NEI 18-04 provides risk-informed licensing basis development for advanced non-light-water NPPs
  - DOE-STD-3009 applies risk ranking using dose and likelihood for nonreactor facility nuclear safety analysis
  - NUREG-1513, NUREG-1520, and 10 CFR Part 70 Subpart H provide guidance used in Integrated Safety Analysis (ISA) for determining performance requirements for nuclear fuel cycle facilities
  - The Q system in Appendix I of IAEA Specific Safety Guide (SSG)-26 uses a reference dose to determine an upper quantity limit of radionuclides in Type A package (greater quantities require Type B)

Development of Proposed Risk Evaluation Guidelines

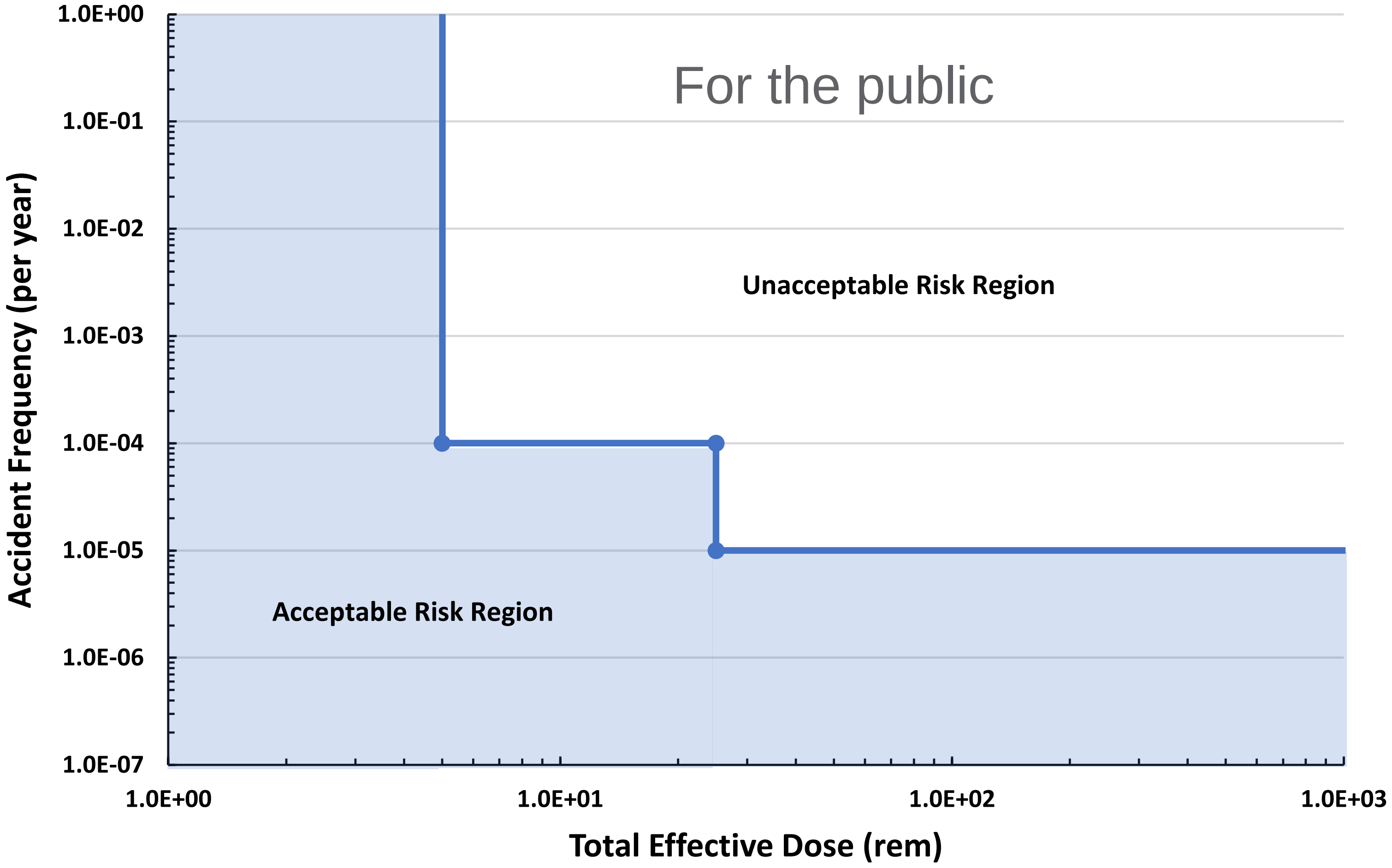
- Hypothetical risk evaluation guidelines for radiation dose based on guidance for ISA (NUREG-1513)
  - 10 CFR Part 70 defines radiation dose levels for **High** and **Intermediate** consequences for the worker and for an individual member of the public
  - NUREG-1520 provides per year frequency definitions for **Unlikely** and **Highly Unlikely** events

Annual Accident Frequency (per event, per year)	Radiation Dose Consequence to the Offsite Public[a]	Radiation Dose Consequence to the Worker[a]	Risk Acceptability
<1E-05	≥25 rem TEDE	≥100 rem TEDE	Acceptable
≥1E-05	≥25 rem TEDE	≥100 rem TEDE	Unacceptable
<1E-04 and ≥1E-05	≥5 and <25 rem TEDE	≥25 and <100 rem TEDE	Acceptable
≥1E-04	≥5 rem TEDE	≥25 rem TEDE	Unacceptable
≥1E-04	<5 rem TEDE	<25 rem TEDE	Acceptable

(a)The radiation dose consequences are presented as a total effective dose equivalent (TEDE), which is based on the integrated committed dose to all receptor organs, thereby accounting for external exposures as well as a 50-year committed effective dose equivalent.

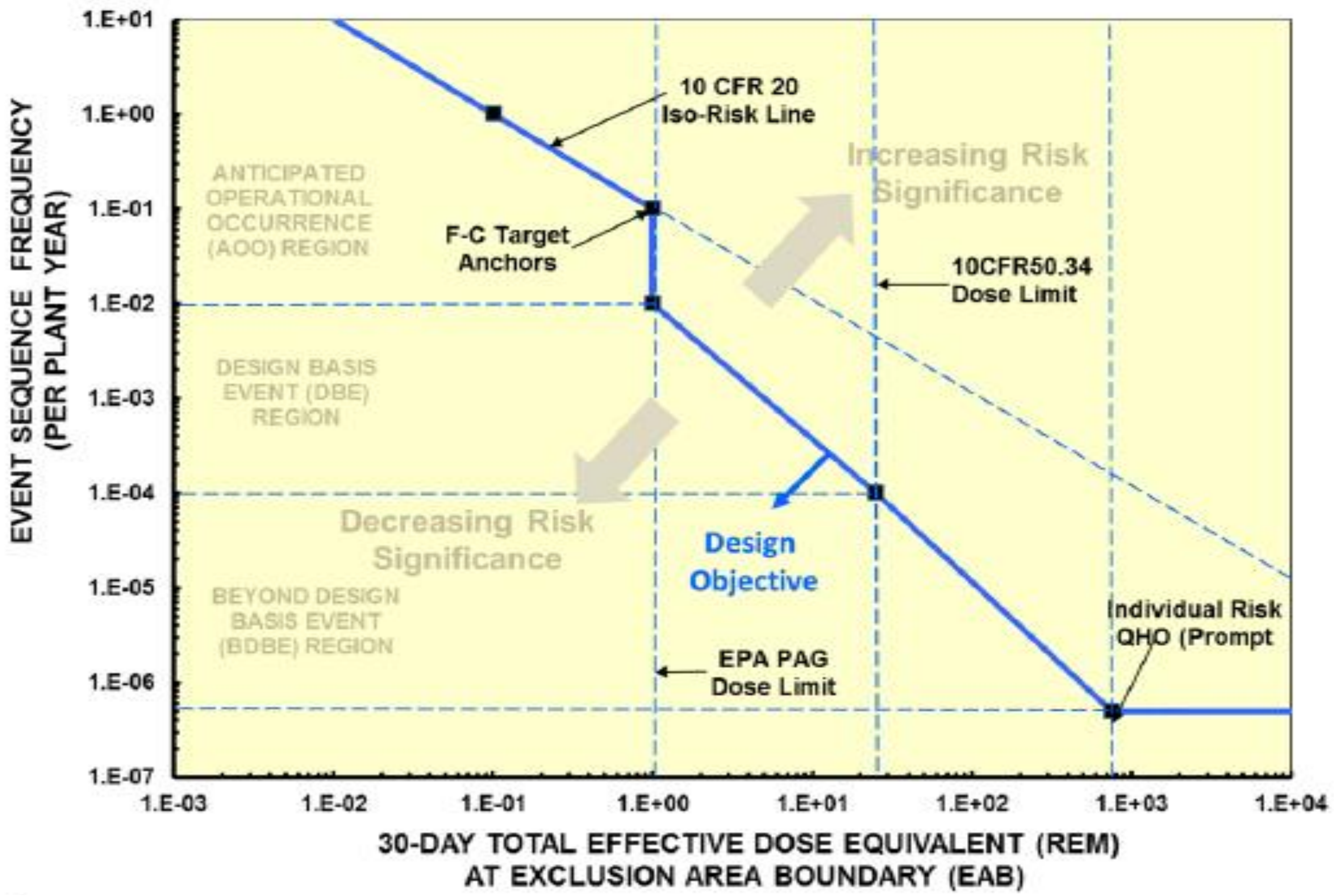
Development of Proposed Risk Evaluation Guidelines

- Hypothetical risk evaluation guidelines for radiation dose based on guidance for ISA (NUREG-1513)
  - 10 CFR Part 70 defines radiation dose levels for High and Intermediate consequences for the worker and for an individual member of the public
  - NUREG-1520 provides per year frequency definitions for Unlikely and Highly Unlikely events



Development of Proposed Risk Evaluation Guidelines

Frequency-Consequence Targets from NEI 18-04, Revision 1



- Illustration of the concept of risk evaluation guidelines based on the combination of radiological dose and likelihood

Development of Proposed Risk Evaluation Guidelines

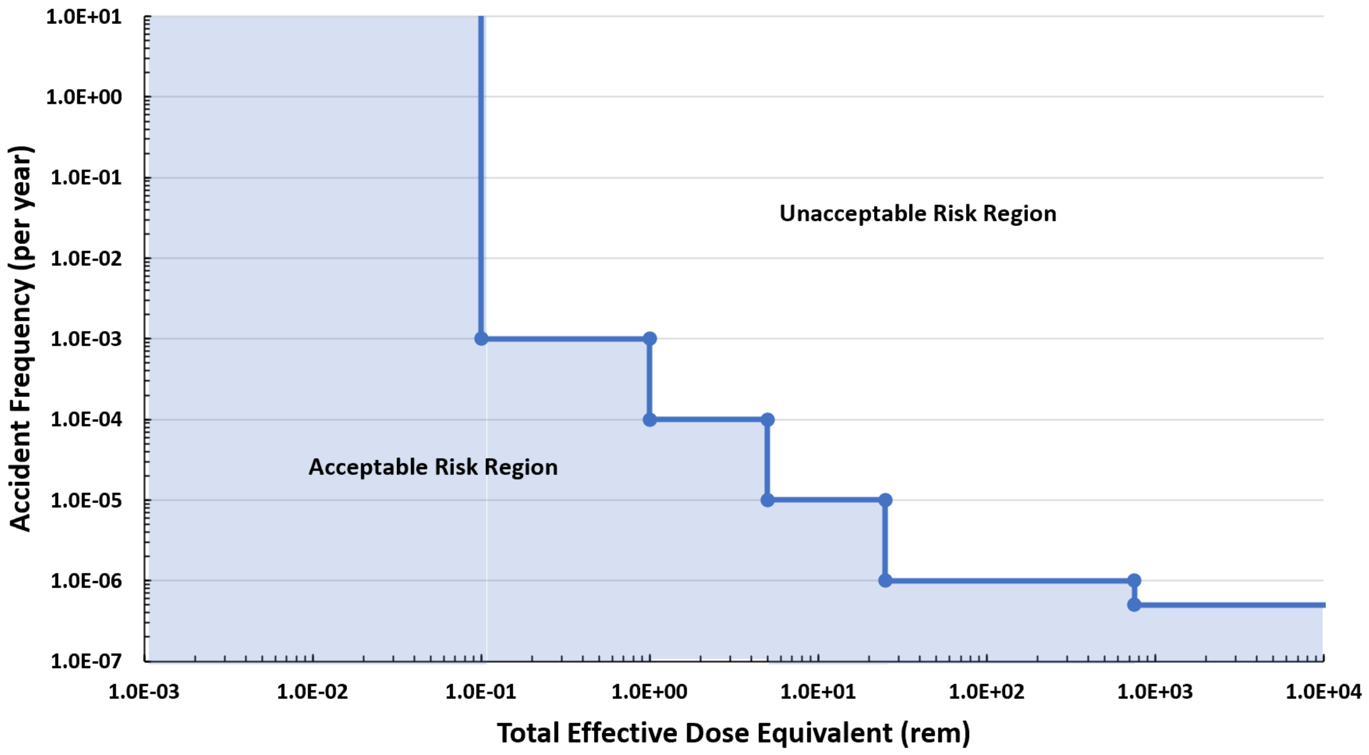
1. Synthesized a set of the limits using the likelihood-consequence pairs from or based on the applications investigated for facilities
2. Converted the radiological dose consequence limits to health effects to the worker and a member of the public by multiplying the:
    - Accident frequency
    - Radiation dose consequence from the accident
    - Conversion factors published by DOE used to convert radiation dose to mortality and morbidity(1)
3. Readjusted some of the likelihood-consequence pairs to ensure that each limit was less than or equal to the QHGs for acute fatalities proposed in the NRC 2008 RIDM report

Note:

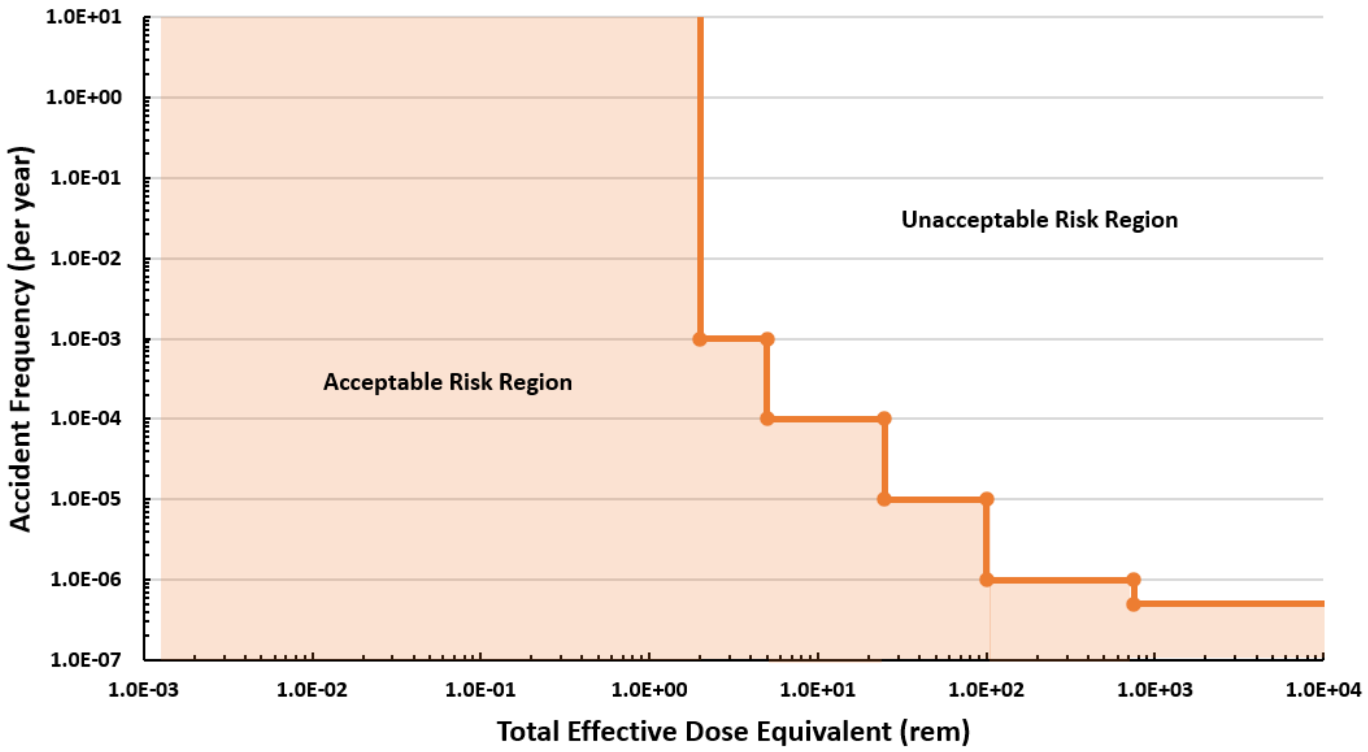
(1) DOE Environmental Policy and Guidance Memorandum, “Radiation Risk from Effective Dose Equivalents (TEDEs),” dated August 2002 based on an Interagency Steering Committee on Radiation Standards (ISCORS) for implementing standards for protection from ionizing radiation

Proposed Risk Evaluation Guidelines

Proposed risk evaluation guidelines compatible with NRC nuclear safety goals, Qualitative Health Objectives, and NRC-proposed QHGs in the NRC 2008 RIDM report



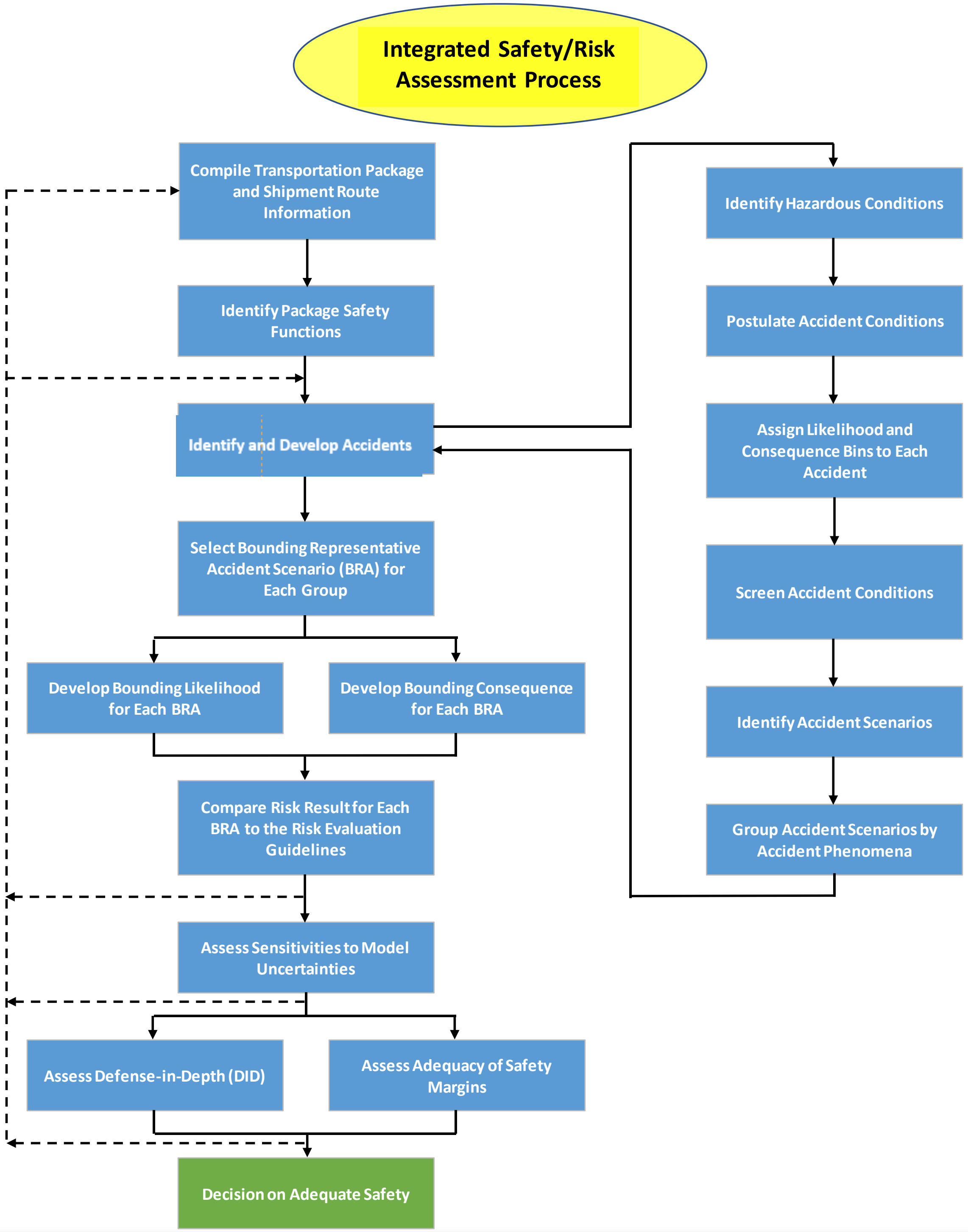
For the Maximum Exposed Member of the Public



For the Worker

Quantitative Risk Assessment Process

- Uses an integrated risk assessment process based on probabilistic risk assessment (PRA) approaches and methods
- Uses standard methods acceptable to both NRC and DOE for assessing the risk of nuclear facilities
- The process was implemented as a demonstration on a hypothetical shipment of the Project Pele TNPP



Integrated Safety/Risk Assessment Process

Compile Transportation Package and Shipment Route Information

Identify Package Safety Functions

Identify and Develop Accidents

Select Bounding Representative Accident Scenario (BRA) for Each Group

Develop Bounding Likelihood for Each BRA

Develop Bounding Consequence for Each BRA

Compare Risk Result for Each BRA to the Risk Evaluation Guidelines

Assess Sensitivities to Model Uncertainties

Assess Defense-in-Depth (DID)

Assess Adequacy of Safety Margins

Decision on Adequate Safety

Identify Hazardous Conditions

Postulate Accident Conditions

Assign Likelihood and Consequence Bins to Each Accident

Screen Accident Conditions

Identify Accident Scenarios

Group Accident Scenarios by Accident Phenomena

Probabilistic Risk Assessment Development Process

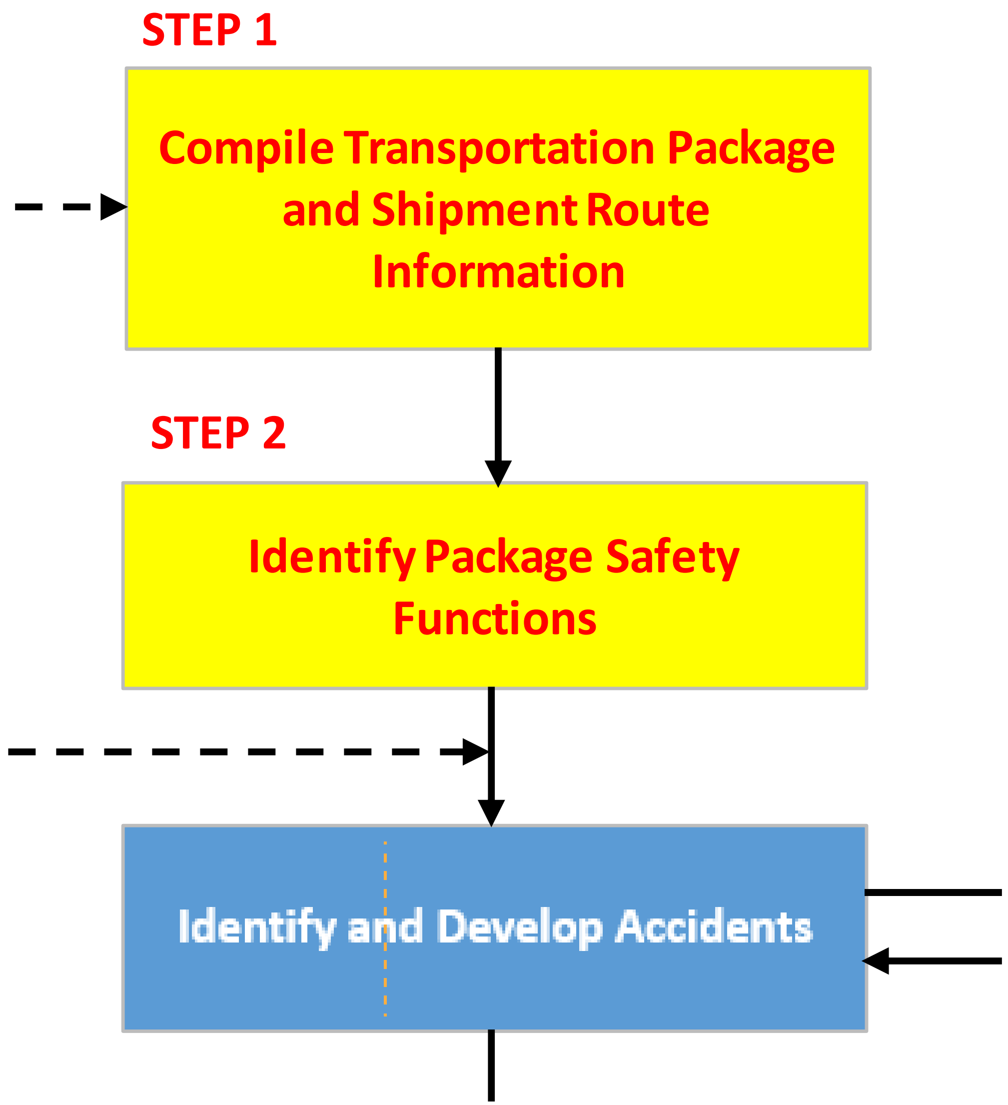
Step 1 – Compile TNPP and Shipment Route Information and Step 2 - Identify Package Safety Functions

Step 1: Information Collection

- TNPP transportation package (Reactor Module only); System design and configuration information, estimated radionuclide inventory at various time periods following reactor shutdown, information on the process for preparing the module for shipment
- Route hazard information, very large truck accident data, and non-vehicle accident data

Step 2: Package Safety Functions

- provide containment of radiological materials
- provide radiation shielding
- maintain a criticality-safe configuration
- maintain passive cooling (considered)



STEP 1

Compile Transportation Package and Shipment Route Information

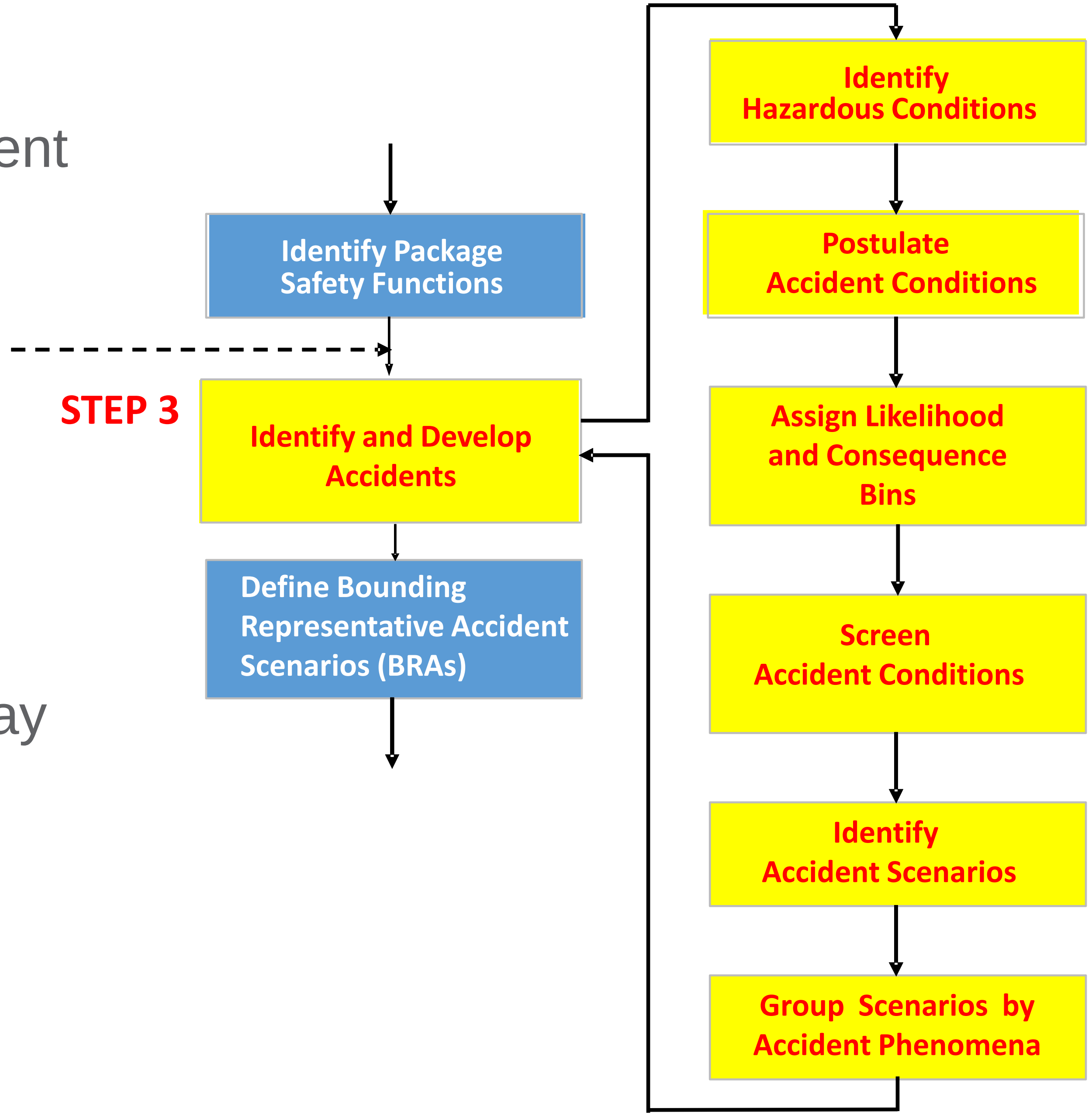
STEP 2

Identify Package Safety Functions

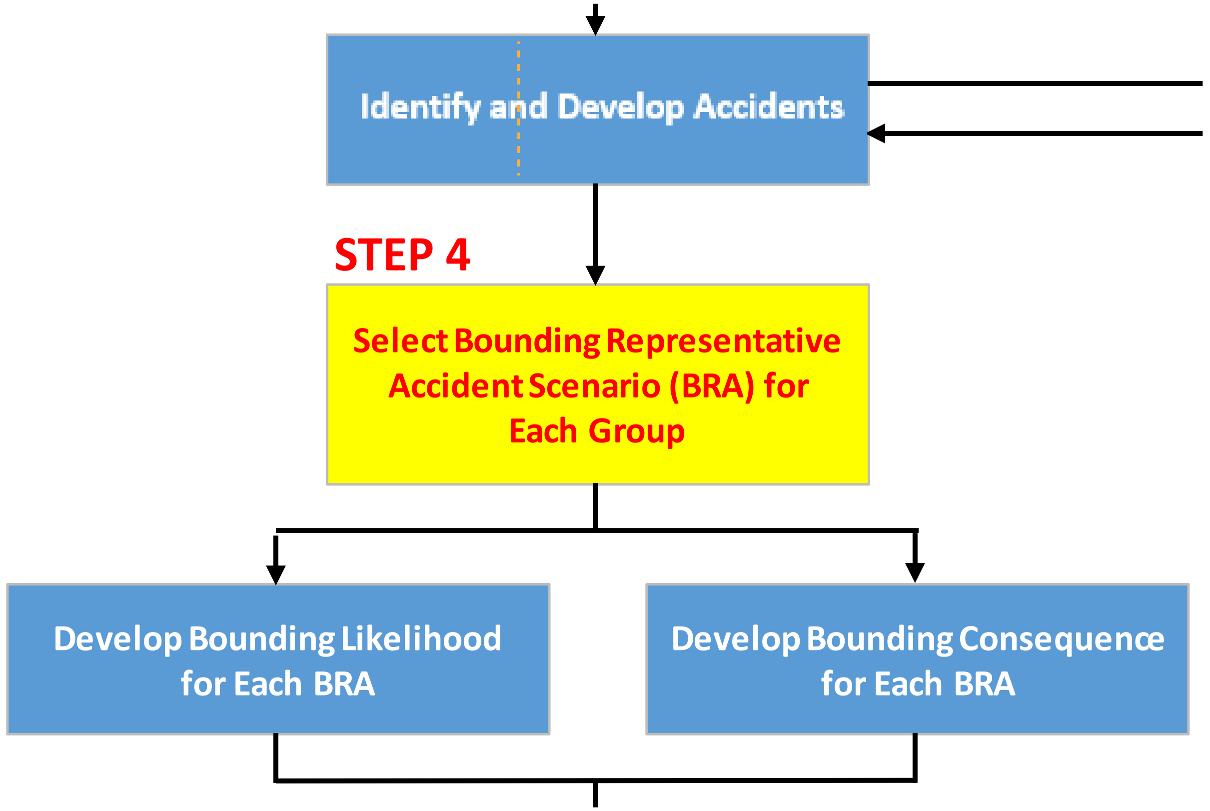
Identify and Develop Accidents

Step 3 – Identify and Develop Accidents

- Performed accident identification and development using Hazard Analysis
- Use of subject matter experts to identify and assess hazardous conditions that could occur during TNPP transport Hazards ID Checklist
- Complete hazardous condition evaluation worksheets that assign likelihood and consequence categories
- Consider both highway accident and non-highway accident initiating events
- Formulate hazardous conditions to contain information needed to define accident scenarios
- Total of 31 accident scenarios representing 8 accident phenomena classes were defined



Step 4 – Define Bounding Representative Accident Scenarios (BRAs)



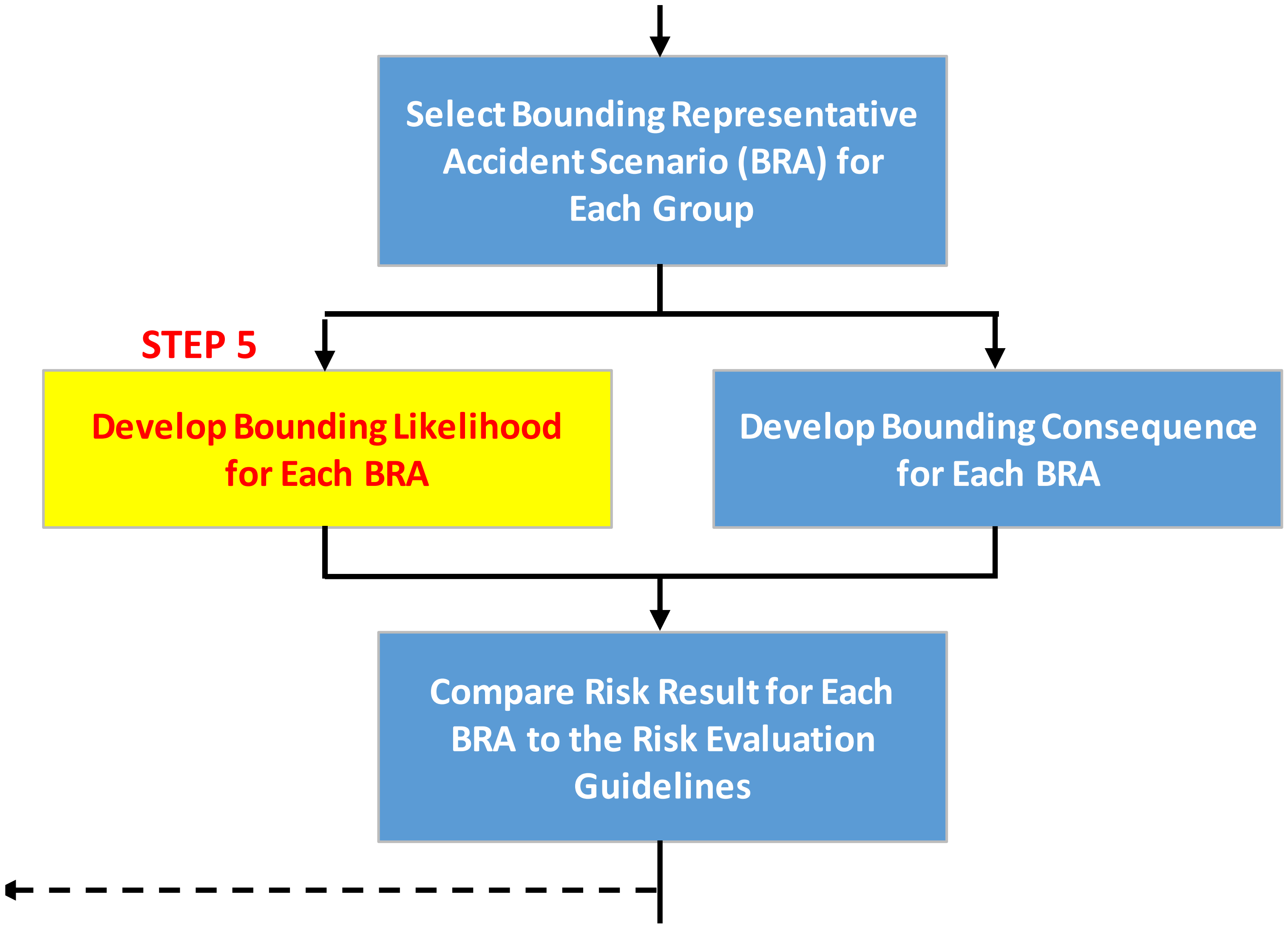
- A BRA is representative of a group of accident scenarios that are phenomenologically similar
- The likelihood for the BRA is determined by the sum of the accidents in the group
- The consequence for the BRA is then determined by the worst consequence of the accidents in the group
- This bounds the risk of all accident scenarios in the group

Step 4 – List of Resulting Bounding Representative Accidents for this Demonstration Implementation

BRA ID	Description
1	Fire-only event that originates inside the transport module.
2	Diesel fuel fire-only event that originates outside the transport module and propagates into the transport module and ignites combustible material in the transport container, which damages the package.
3	Hard-impact highway accident that leads to release of radioactive material and loss of shielding. Includes impact with heavy vehicles and unyielding objects (e.g., concrete abutments or rock embankments), drops to a lower elevation, or rollovers.
4M	Less than a hard impact highway accident that results in release of some radiological material and loss of shielding. Medium impact that involves a severe collision with a light vehicle.
4L	Less than a hard-impact highway accident that results in no release of radiological material but some degradation of external shielding. Light impact such as a jackknife, impact with a yielding object (e.g., a road sign or soil embankment), or impact with a light vehicle that is not severe.
5H	Hard impact highway accidents that result in fire with exception of collision with a tanker carrying flammable material.
5M	Medium impact highway accidents (i.e., severe collision with a light vehicle) that results in fire.
6	Collision with a tanker carrying flammable material that leads to fire.
7	Loss of non-pressurized reactor containment boundary not caused by a road accident but rather by human error and failures of containment features.
8	Loss of pressurized reactor containment boundary not caused by a road accident but rather by human error and failures of containment features.
9A	Addition of moderator and a possible change in core geometry caused by a drop into body of water that results in criticality.
9B	Addition of moderator and possible change in core geometry caused inundation of the core with fire suppression water or other hydrogenous material that enters the core in sufficient quantities to cause criticality after a crash that results in fire and TNPP damage
10	Control rod withdrawal (or another reactivity insertion event) caused by impact from a road accident that results in criticality.

Step 5 – Develop Likelihood for Each BRA

- Very large truck accident data
  - Frequency of impacts, fires, non-impacts, rollovers
  - Use route specific data to the extent possible
- Package-specific failures not in accident rate data
  - Internal-initiated fires, random failures, human error
- Specific route hazard information
  - such as bridges, bodies of water, steep drops to a lower elevation



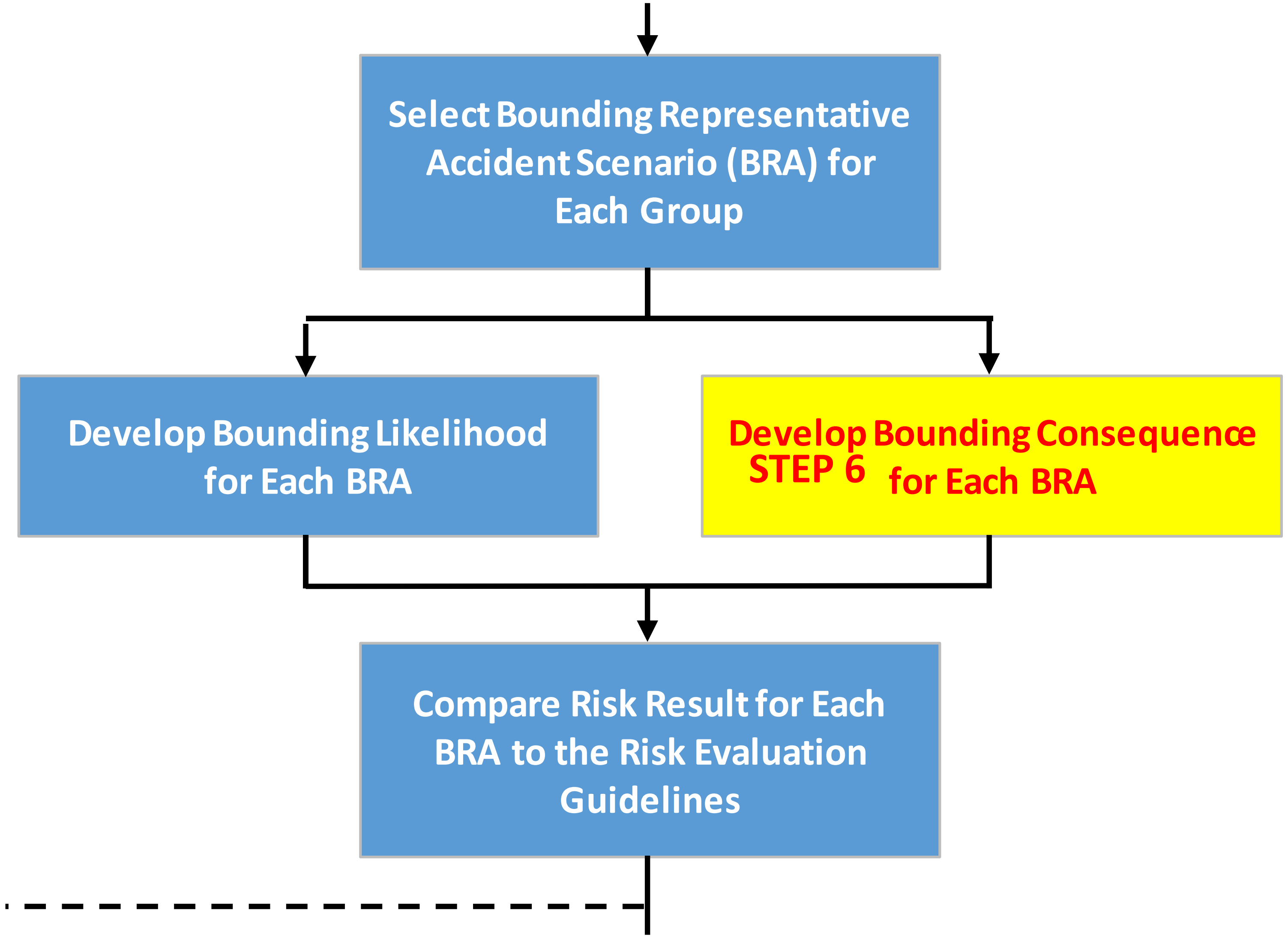
Step 5 – Develop Bounding Likelihood for Each BRA

- The assumed hypothetical route for this demonstration was from Idaho National Lab to White Sands NM (about 1300 miles of Interstate)
- GIS was used to identify portions of the route where hazards existed to compute the percentage of total route where the hazard existed. This includes:
    - Steep drop-offs. If an accident happened here, the truck and package could drop or roll to lower elevation.
    - Sufficient slope to a body of water deep enough to submerge the reactor vessel. If an accident happened here, a criticality could occur.
- Using very large truck crash rate data and hazard data, an accident frequency was computed.

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Step 6 – Develop Bounding Consequence for Each BRA

- Estimated effective radiation dose from each dose pathway methodology is based on Appendix I of IAEA SSG-26, with refinements mostly to account for the public receptor.
- The source term was calculated using DOE/NRC methods/data used to determine source term (e.g., MAR × DR × ARF × RF × LPF)
- Source term includes used fuel inventory and inventories diffused into reactor during operation
  - Fuel (concerns about performance under mechanical impact)
  - Core/compact (concerns about fuel qualification)
  - Pressure Boundary (concerns about plating)



Select Bounding Representative Accident Scenario (BRA) for Each Group

Develop Bounding Likelihood for Each BRA

Develop Bounding Consequence for Each BRA

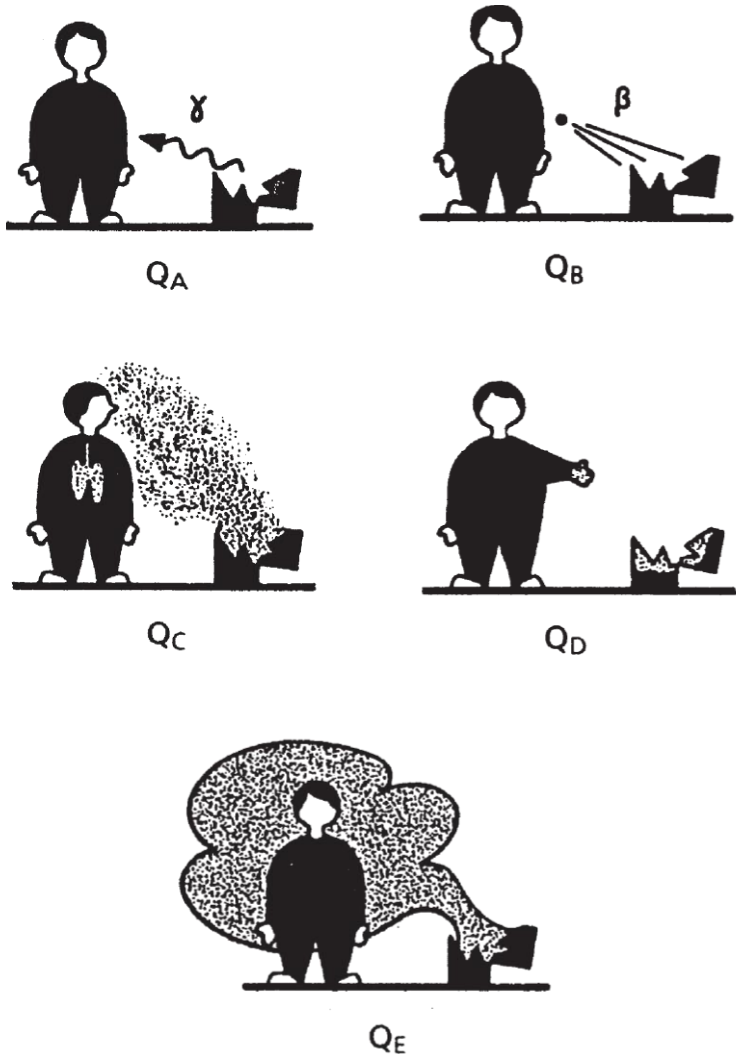
STEP 6

Compare Risk Result for Each BRA to the Risk Evaluation Guidelines

Material at Risk (MAR), Damage Ratio (DR), Airborne Release Fraction (ARF), Release Fraction (RF), and Leak Path Factor (LPF)

Step 6 – Develop Consequence for Each BRA

- Radiological dose pathways from IAEA SSG-26 (Q System) were used which are the same as in NRC regulations).
  - External Photon Dose (Q_A): External dose due to released material (with added contribution for unreleased material for an individual at given distances from the package with degraded shielding.)
  - External Beta Dose (Q_B): External direct dose from skin contamination due to released material for individual at given distances from the release.
  - Inhalation Dose (Q_C): : Inhalation dose calculated using an airborne source term and human uptake value
  - Skin contamination (Q_D): Calculated from equivalent skin dose but not used because responders are assumed to use protective clothing
  - Neutron Dose: Determined by PNNL to be a minimal contributor in the demonstration for released material. Gamma dominates

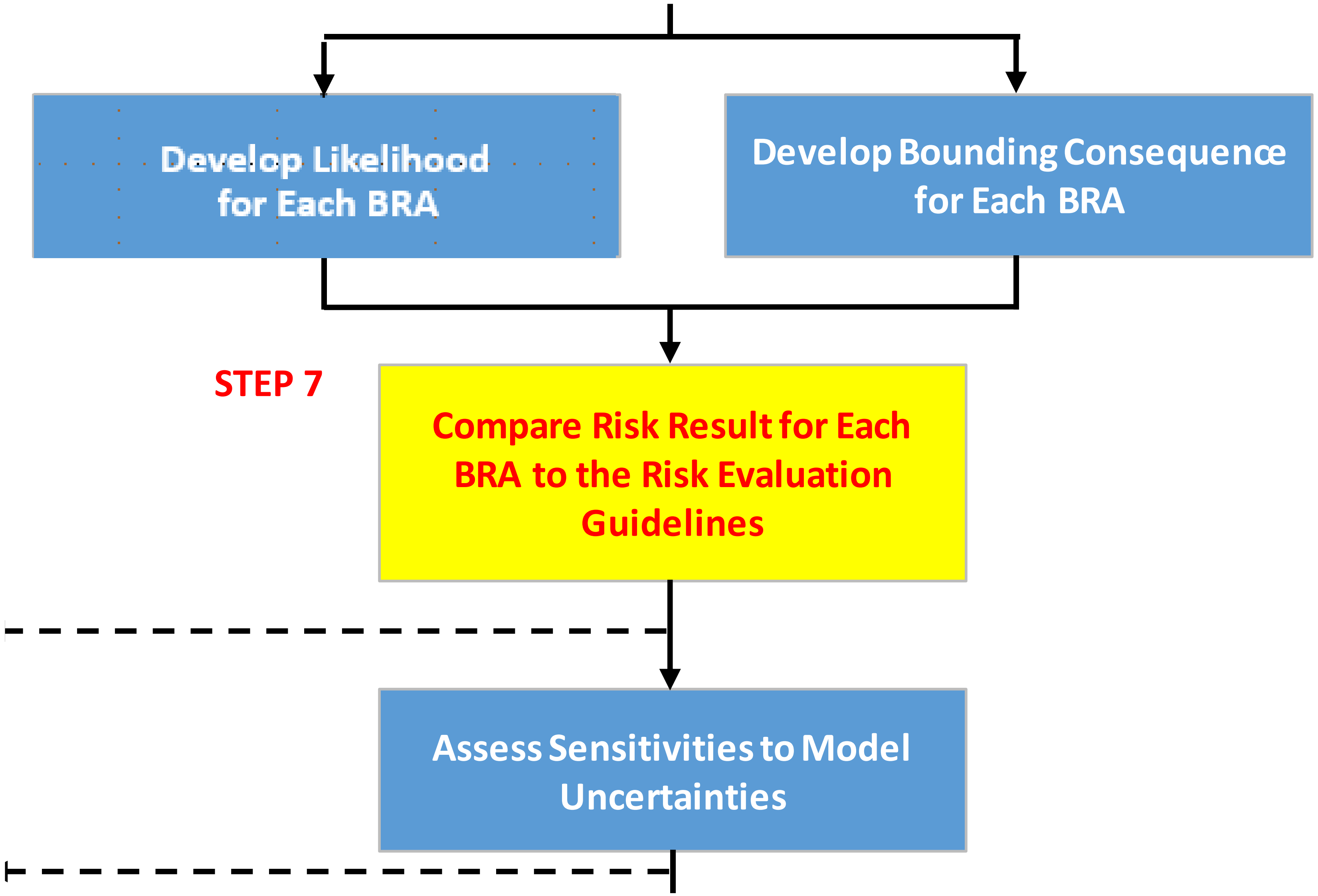


*Other pathways excluded by Q system: (e.g., resuspension, skyshine, drinking water ingestion) are not significant contributors for irradiated fuel and would likely be mitigated by the emergency response

**Submersion pathway (see Q_E in the Figure) excluded because the release is outdoors where there will be a high level of dilution

Step 7 – Compare Risk Results to Proposed Risk Evaluation Guidelines

The risk results are reported as the likelihood and consequence for each Bounding Representative Accident



Develop Likelihood for Each BRA

Develop Bounding Consequence for Each BRA

STEP 7

Compare Risk Result for Each BRA to the Risk Evaluation Guidelines

Assess Sensitivities to Model Uncertainties

Example Comparisons to Risk Evaluation Guidelines

When the accident frequency is
≤1E-05 and >1E-06 per year

Then the dose limits are:
≥5 and <25 rem TEDE for a member of the public
≧25 and <100 rem TEDE for a worker

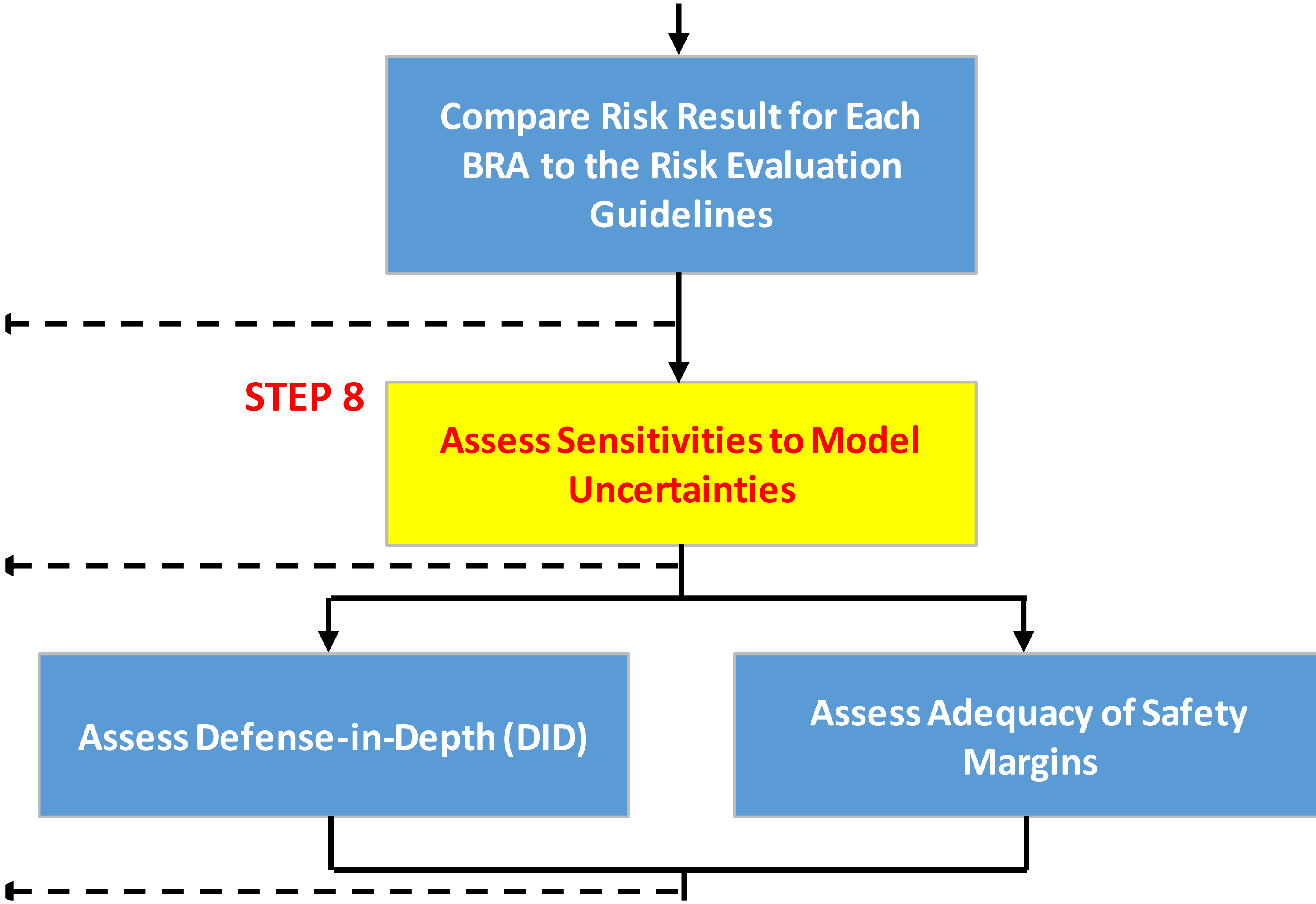
or

When the accident frequency is
≤1E-04 and >1E-05 per year

Then the dose limits are:
≥1 and <5 rem TEDE for a member of the public
≧5 and <25 rem TEDE for a worker

Step 8 – Assess Sensitivities and Model Uncertainties

- Sensitivity studies were performed to address the impact of key assumptions and sources of uncertainty (examples are provided later)
- Sensitivity studies were also considered to address the impact of compensatory actions
- Limited parameter uncertainty analysis typical of PRAs was performed
  - Data for a parametric uncertainty analysis is limited
  - Because each BRA is evaluated with a bounding estimate of the likelihood and consequence


Compare Risk Result for Each BRA to the Risk Evaluation Guidelines

STEP 8

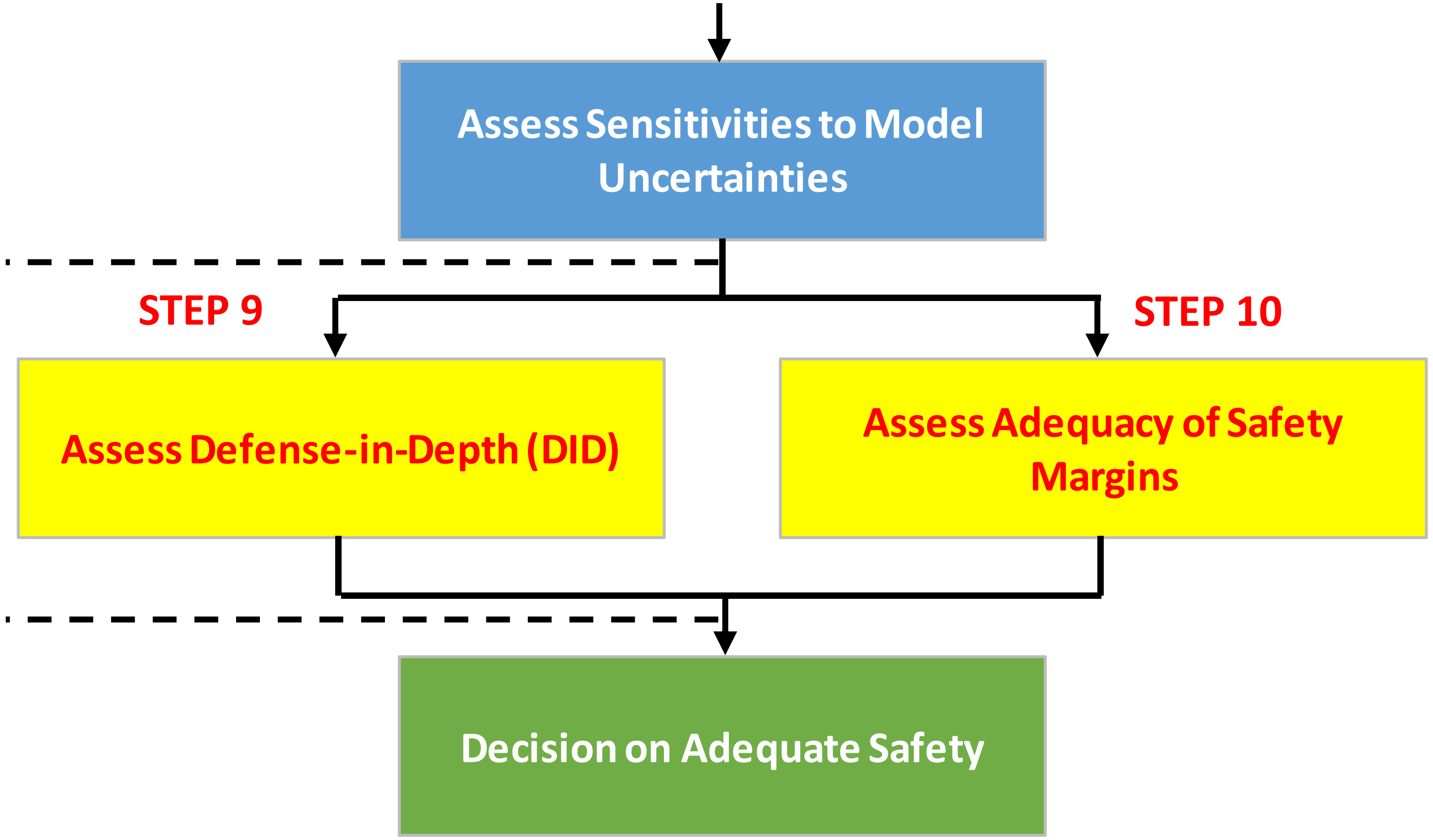
Assess Sensitivities to Model Uncertainties

Assess Defense-in-Depth (DID)

Assess Adequacy of Safety Margins

Step 9 – Assess Defense-in-Depth
Step 10 – Assess Adequacy of Safety Margins

- DID is a design and operational philosophy that calls for multiple layers of protection to prevent and mitigate accidents
  - multiple physical barriers to prevent release of radiation
  - passive features
  - PRA shows low risk
  - administrative controls
  - accident recovery plans
- Safety margin is a measure of the conservatism that is employed in a design or process to assure a high degree of confidence that it will perform a needed function
  - Typically to demonstrate adherence to acceptable codes and standards



Assess Sensitivities to Model Uncertainties

STEP 9

STEP 10

Assess Defense-in-Depth (DID)

Assess Adequacy of Safety Margins

Decision on Adequate Safety

Example Risk Results for Bounding Representative Accidents

BRA 2 – Fire Only that Originates from Outside the Transport Container

Accident Risk	Worker Dose (rem TEDE)	Public Dose (rem TEDE)	Accident Frequency (per year)	Applicable Proposed Risk Evaluation Guidelines from Table 4.7 of this Report
Accident Consequence (from Table 7.6)			2.0E-06	≥5 and <25 rem TEDE for a member of the public ≥25 and <100 rem TEDE for a worker when the accident frequency is ≤1E-05 and >1E-06
MAR contribution from released material				
TRISO Fuel	0	0		
Core Structure	1.0E-03	2.6E-04		
Cooling System	1.2E-03	2.5E-04		
Contribution from Unreleased Material				
Degraded shielding	0	0		
Total Radiation dose	2.3E-03	5.1E-04		
Accident Frequency assuming one trip per year (from Table 6.16)				
COMPARISON TO RISK EVALUATION GUIDELINE				Acceptable

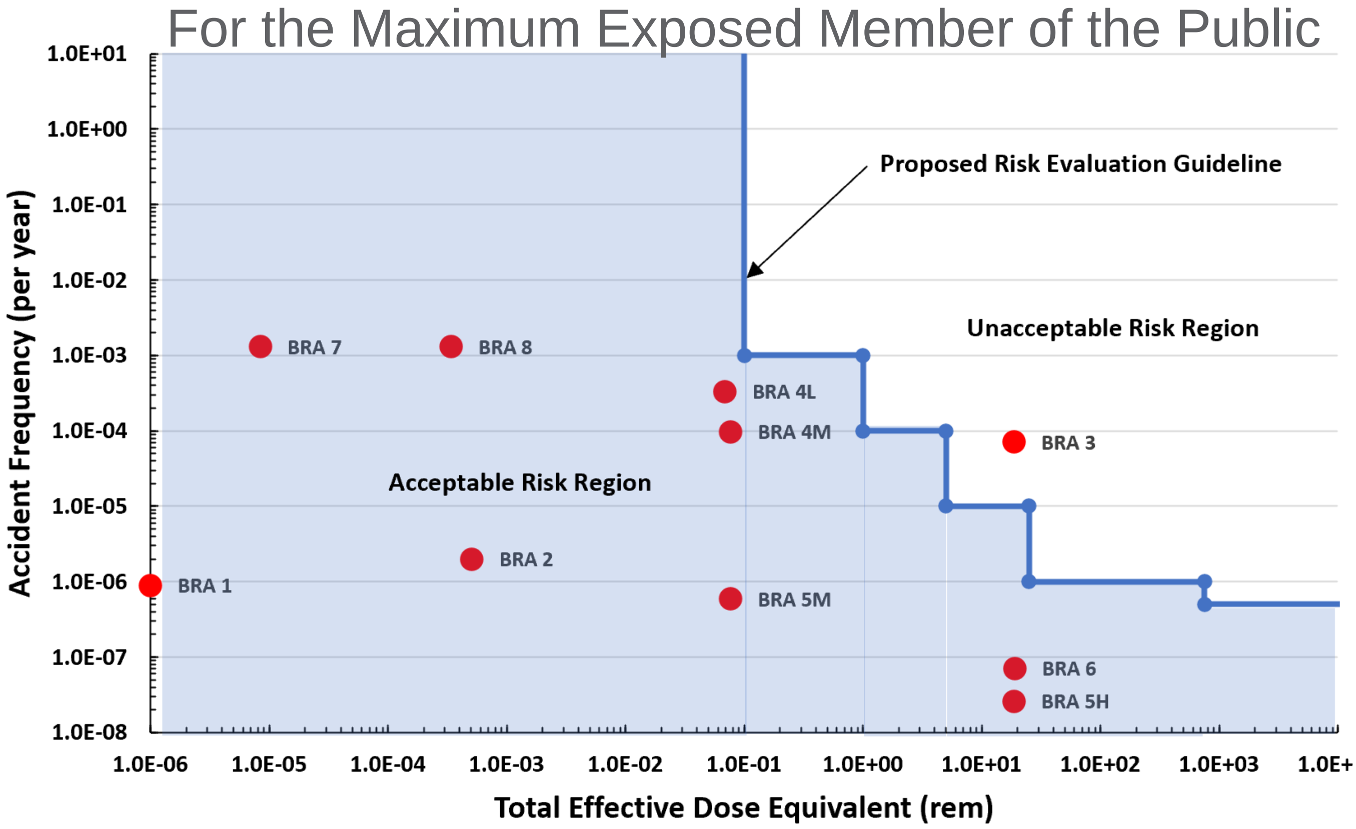
Example Risk Results for Bounding Representative Accidents

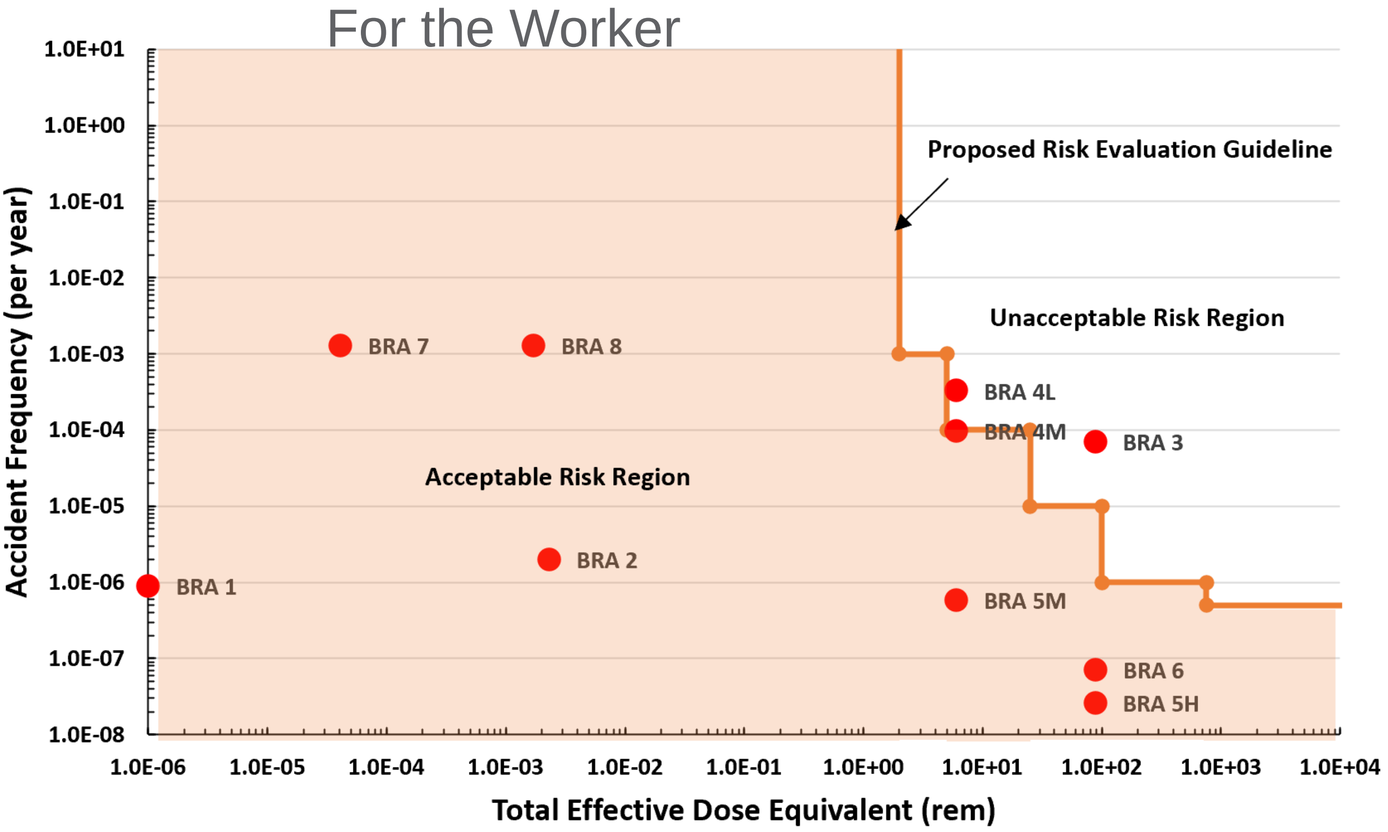
BRA 3 – Hard Impact Road Accident that leads to release of radioactive material and degraded shielding

Accident Risk	Worker Dose (rem TEDE)	Public Dose (rem TEDE)	Accident Frequency (per year)	Applicable Proposed Risk Evaluation Guidelines from Table 4.7 of this Report
Accident Consequence (from Table 7.6)				≥1 and <5 rem TEDE for a member of the public ≥5 and <25 rem TEDE for a worker when the accident frequency is ≤1E-04 and >1E-05
MAR contribution from released material				
TRISO Fuel	80.9	18.5		
Core Structure	5.2E-01	1.3E-01		
Cooling System	3.1E-01	6.3E-02		
Contribution from Unreleased Material				
Degraded shielding	6.0	6.9E-02		
Total Dose	87.7	18.8		
Accident Frequency assuming one trip per year (from Table 6.16)			7.1E-05	
COMPARISON TO RISK EVALUATION GUIDELINE				Unacceptable

Summary of Demonstration TNPP PRA Risk Results

- Risk for the Bounding Representative Accident Results Shown Graphically


For the Maximum Exposed Member of the Public


For the Worker

Note: BRA 9A and 9B - two kinds of flooded criticality events - are not shown here because their consequences were not calculated given that their likelihoods were determined to be extremely low.
BRA 10 – reactivity insertion caused by crash impact leading to criticality was not developed because it was anticipated the demonstration design will preclude (or design against) this possibility (e.g., using locking mechanisms)

Sensitivity Studies

- Selection and definition of the sensitivity cases to be performed were based on:
  - Comprehensive examination of specific lists of assumptions and bases for the hazards, likelihood, and consequence analysis, and
  - Compensatory measures listed for the demonstration design to reduce or mitigate risk
- Quantitative sensitivity studies defined and performed
  1. Decay time after operation
  2. Distance of a member of the public to point of release
  3. Exposure time to a damaged TNPP package
  4. Uncertainty in source term fraction estimates
  5. Restriction of transport during extreme weather (compensatory action)
  6. Transport at night (compensatory action)
- In sensitivity studies - reran the models for applicable BRA to determine new risk results

Example Sensitivity Study Results

Results of Sensitivity Study on decay time after shutdown on BRA 3 – Hard Impact Road Accident

Sensitivity Study for Impact of Decay after Shutdown				
Delay from Shutdown to Transport	Worker Dose (rem TEDE)	Public Dose (rem TEDE)	Accident Frequency (per year)	Applicable Proposed Risk Evaluation Guidelines from Table 4.7 of this Report
Accident Consequence (from Table 7.6)				
30 days	1420	319		≥1 and <5 rem TEDE for a member of the public ≥5 and <25 rem TEDE for a worker when the accident frequency is ≤1E-04 and >1E-05
60 days	208	45.9		
90 days	87.7	18.8		
1 year	14.5	3.3		
2 years	7.8	1.7		
Accident Frequency assuming one trip per year (from Table 6.16)			7.1E-05	
COMPARISON TO RISK EVALUATION GUIDELINE				Acceptable for delay times of 1 year or more

Uncertainty Analysis and Insights

- In general, there is insufficient data to perform parametric uncertainty analysis (hence the sensitivity studies)
- However, a limited uncertainty analysis was performed on the very large truck accident data

Accident Risk	Worker Dose (rem TEDE)	Public Dose (rem TEDE)	Accident Frequency (per year)	Applicable Proposed Risk Evaluation Guidelines from Table 4.7 of this Report
Accident Consequence by MAR Contribution (Radiation dose from Table 7.6)				≥1 and <5 rem TEDE for a member of the public ≥5 and <25 rem TEDE for a worker when the accident frequency is ≤1E-04 and >1E-05 ≥0.1 and <1 rem TEDE for a member of the public ≥2 and <5 rem TEDE for a worker when the accident frequency is ≤1E-03 and >1E-04
MAR contribution from Released Material				
TRISO Fuel	0	0		
Core Structure	2.6E-02	6.5E-03		
Cooling System	9.3E-03	1.9E-03		
Contribution from Unreleased Material				
Degraded shielding	6.0	6.9E-02		
Total Dose	6.0	7.7E-02		
Accident Frequency assuming one trip per year (from Table 6.16)			9.7E-05	
Accident Frequency multiplied by 41% to match highest state and year combination			1.4E-04	Worker risk changed from acceptable to unacceptable from comparison to risk evaluation guidelines
COMPARISON TO RISK EVALUATION GUIDELINE				Unacceptable

- The limited uncertainty analysis did not change the conclusions about risk of the BRAs with the exception above for BRA 4 Medium Impact Accident which becomes unacceptable.

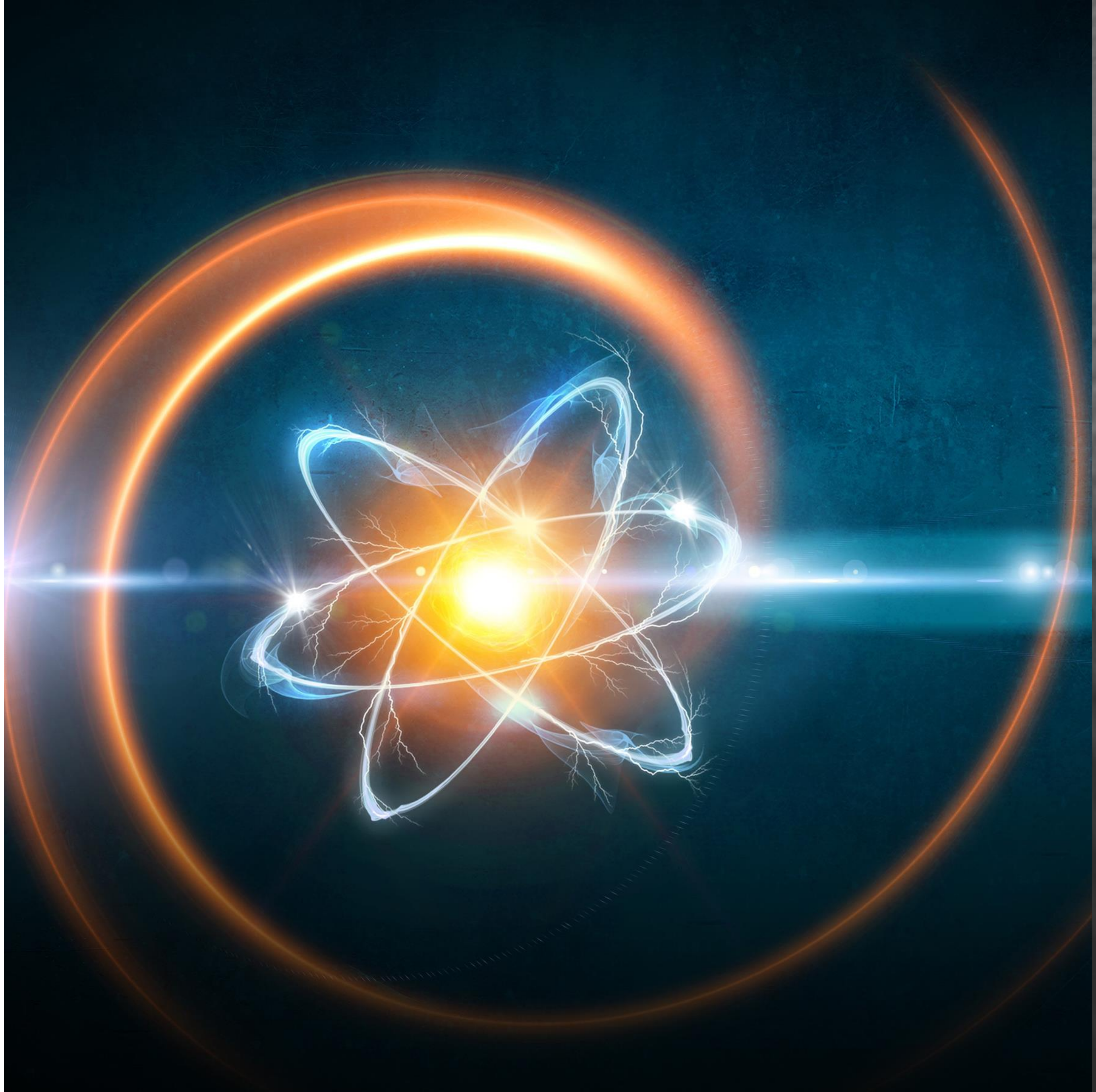
Key Insights from Demonstration PRA Results and Sensitivity Studies

- Allowing the TNPP reactor core to decay up to one year after it has been in operation for 3 years will result in an acceptable level of risk for all BRAs based on the proposed risk evaluation guidelines.
- The conclusions about the risk of BRAs are not sensitive to the uncertainty in estimating the source term factors.
- The conclusions about the risk of BRAs are not sensitive to increasing the accident duration from 30 minutes to one hour.
- The conclusions about the risk of BRAs are not sensitive to decreasing the distance that the public is to the accident to be the same distance as the worker is to the accident, except for light impact accidents (BRA 4L and BRA 4M) in which a direct dose of 6 rem is estimated from degraded shielding.
- While certain compensatory actions are feasible to implement, their impact is difficult to evaluate

Summary

- Current NRC regulations provide a feasible regulatory pathway for licensing a first-of-kind transportation of a microreactor with irradiated fuel
- Proposed workable risk evaluation guidelines were developed that are compatible with QHGs proposed in the 2008 NRC RIDM report
- The risk-informed PRA-based approach does support an application to the NRC for approval of shipment of a TNPP package (containing irradiated fuel)
- The demonstration application of this approach for a hypothetical single shipment per year of the Project Pele microreactor has shown that the proposed risk evaluation guidelines can be met

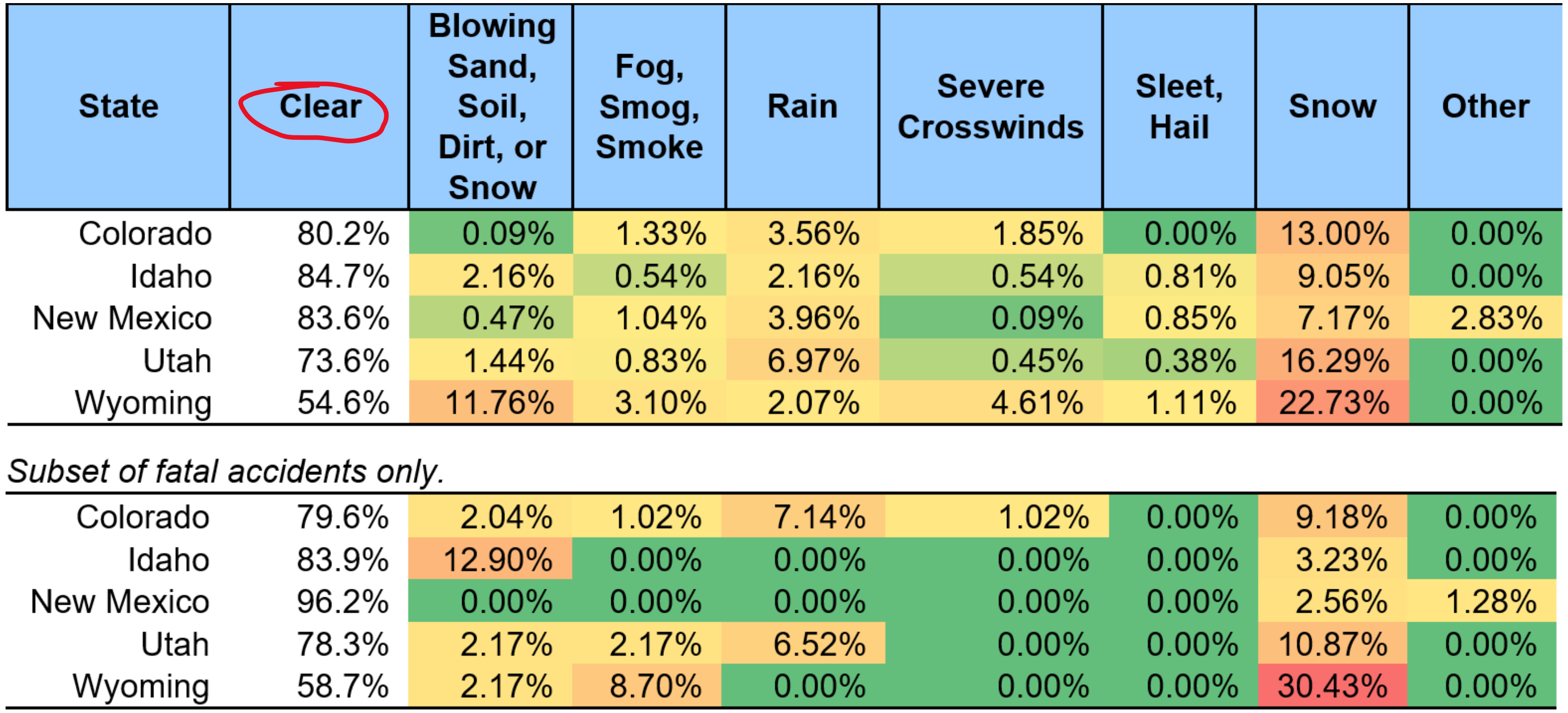
Questions
&
Discussion



Backup Slides

Sensitivity Study Insights

Certain candidate sensitivity studies were screened out for feasibility reasons



State	Clear	Blowing Sand, Soil, Dirt, or Snow	Fog, Smog, Smoke	Rain	Severe Crosswinds	Sleet, Hail	Snow	Other
Colorado	80.2%	0.09%	1.33%	3.56%	1.85%	0.00%	13.00%	0.00%
Idaho	84.7%	2.16%	0.54%	2.16%	0.54%	0.81%	9.05%	0.00%
New Mexico	83.6%	0.47%	1.04%	3.96%	0.09%	0.85%	7.17%	2.83%
Utah	73.6%	1.44%	0.83%	6.97%	0.45%	0.38%	16.29%	0.00%
Wyoming	54.6%	11.76%	3.10%	2.07%	4.61%	1.11%	22.73%	0.00%

Subset of fatal accidents only.

State	Clear	Blowing Sand, Soil, Dirt, or Snow	Fog, Smog, Smoke	Rain	Severe Crosswinds	Sleet, Hail	Snow	Other
Colorado	79.6%	2.04%	1.02%	7.14%	1.02%	0.00%	9.18%	0.00%
Idaho	83.9%	12.90%	0.00%	0.00%	0.00%	0.00%	3.23%	0.00%
New Mexico	96.2%	0.00%	0.00%	0.00%	0.00%	0.00%	2.56%	1.28%
Utah	78.3%	2.17%	2.17%	6.52%	0.00%	0.00%	10.87%	0.00%
Wyoming	58.7%	2.17%	8.70%	0.00%	0.00%	0.00%	30.43%	0.00%

- This figure shows the environmental condition at the time of the very large truck crash based on Motor Carrier Management Information system data.
- It indicates most accidents occur during clear weather - probably because the weather is usually clear.
- The change in the accident rate for poor conditions could not be determined from the data because the very large truck travel volume was not known for the different environmental conditions

List of Hazard Analysis/Accident Sequence Assumptions

Description of Assumptions (Sheet 1 of 2)
1. The dominant radiation dose risk is associated with the Reactor Module because it contains the reactor, the fuel, portions of the primary cooling system and nearly all of the radiological material inventory.
2. The Reactor Module also includes spent fuel after a specified period of decay s described..
3. There is no gas cleanup system in the design, so its contribution to radioactive transportation inventory is not considered
4. Submersion of the reactor vessel into a body of water could lead to a criticality based on demonstration design.
5. No credit can be taken for a HMIS (a health monitoring system) given that one has not yet been defined, though such a system could reduce the risk from certain kinds of accidents.
6. Loss of passive heat transfer from the reactor in the TNPP Package to the environment could lead to pressurization of the reactor containment boundary but decay heat by itself would not lead to failure of a containment seal or device
7. There is only enough combustible material inside the Reactor Module in the form of cable and wire jacket and insulation to lead to a small fire.
8. No (or minimal) other flammable material, other than cable and wire jacket and insulation and minimal quantities of grease and oil, exist in the Reactor Module
9. There will be energized electrical components in the TNPP Package during transport associated with parameter monitoring, lighting, and ventilation
10. The quantity of diesel fuel in the transport vehicle is about 300 gallons
11. The only external fire of sufficient magnitude to propagate into the TNPP Package from the outside is a diesel fuel fire (though engine and other fires could propagate to a diesel fire).

List of Hazard Analysis/Accident Sequence Assumptions

Description of Assumptions (Sheet 2 of 2)
12. For hard impacts followed by fire, including a collision with a tanker carrying flammable liquid, the proportion of collisions that involves an explosion (e.g., deflagration or detonation) is very small compared to those that involve just fire. Therefore, hard impact followed by an explosion were not separately evaluated.
13. A shipment would not deliberately be made in weather conditions so severe that the design/integrity of package would be exceeded.
14. Extreme weather events that can contribute to the occurrence of highway accidents that damage the TNPP Package are included in the large truck data, and therefore, do not need to be separately considered in separate scenarios.
15. There would be no specific control of passing or oncoming vehicles (i.e., collision with other vehicles was assumed possible) in development of the likelihood estimates.
16. Hazardous conditions qualitatively evaluated to be low risk were not significant enough to be carried forward for detailed accident analysis
17. The TNPP being transported has not experienced a design basis event (DBE) or beyond design basis event (BDBE) during operation that would have affected diffusion rates during operation

NRC REVIEW OF A RISK-INFORMED METHODOLOGY FOR A TRANSPORTABLE MICRO-REACTOR PACKAGE

ACRS Subcommittee on Fuels, Materials, and Structures
November 17, 2023

Bernard White, Senior Project Manager
Jonathan Marcano, Senior Risk and Reliability Analyst
Division of Fuel Management
Office of Nuclear Material Safety and Safeguards

Agenda

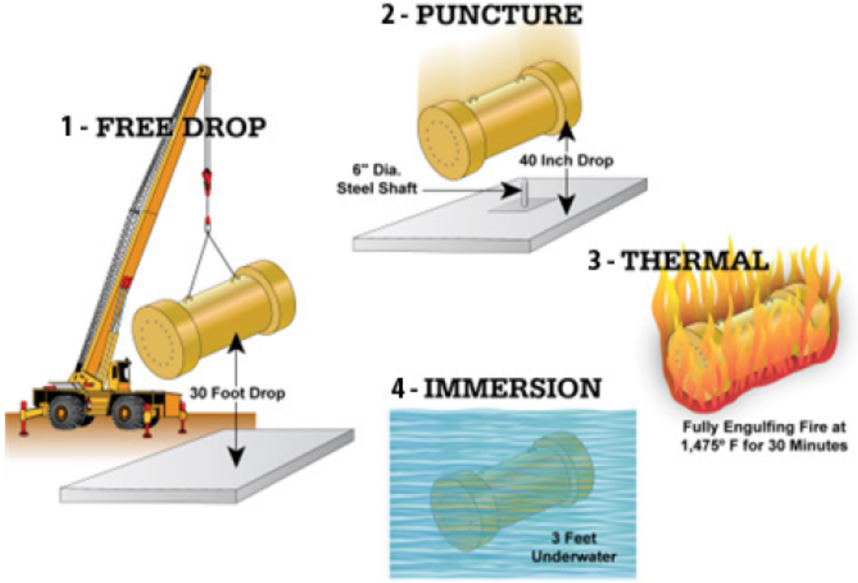
- Adequate transportation regulatory framework
- Extensive regulatory engagements on Project Pele
- Alternate package approval pathways, including risk-informed methodology
- U.S. Nuclear Regulatory Commission (NRC) review of the risk-informed methodology
- Next steps in development of and preparation to review a package application in CY2024

Regulations for Radioactive Material Transport

- NRC and U.S. Department of Transportation (DOT) co-regulate transportation of radioactive material
- DOT
  - Regulates all hazardous materials, including radioactive material (RAM), for all modes of commercial transportation
  - Is the U.S. Competent Authority for import and export of RAM
  - Sets safety standards for the classification of RAM, for the design specifications and performance requirements of Type A packages (other than fissile materials) and for low specific activity (LSA)/surface contaminated object (SCO) RAM, and for the external radiation fields, labeling, and marking of all RAM packages and vehicles.
  - Authorizes shipment in NRC-approved packages
- NRC
  - Regulates domestic Type B and fissile packages
  - Conducts the technical review and provides recommendations to DOT on foreign packages (i.e., revalidations)

Package Performance Tests and Conditions

- Normal conditions of transport (10 CFR 71.71)
  - Hot and cold temperatures
  - Reduced and increased external pressure
  - Vibration
  - Water spray
  - Free drop (1 to 4 feet)
  - Corner drop
  - Compression test
  - Penetration test



- Hypothetical accident conditions (10 CFR 71.73)
  - 30-foot drop test
  - 40-inch puncture test
  - 30-minute fire at 1,475 degrees Fahrenheit
  - Water immersion test (fissile/non-fissile)

Package Performance Criteria

- Criticality safety
  - Single package (10 CFR 71.55)
  - Array of packages (10 CFR 71.59)
- Shielding
  - Maximum dose rates for all packages (10 CFR 71.47 & 49 CFR 173.441)
- Additional requirements for Type B packages
  - Containment criteria for normal form material (10 CFR 71.51(a)(1) and (2))
  - Dose rates after hypothetical accident conditions (10 CFR 71.51(a)(2))

OPTIMUS-L Package
Photo courtesy of NAC International

What is Project Pele?

- Strategic Capabilities Office (SCO) in the U.S. Department of Defense contracted with BWX Technologies, Inc., to design and fabricate a transportable micro-reactor
  - – Producing less than 5 MW
  - – Operable for 3+ years
- Reactor module fits into a single custom-developed International Organization for Standardization container which resembles a **CON**tainer **EX**press (**CONEX**) box

Levels of Regulatory Engagement for Project Pele

- Scope of Memorandum of Understanding between NRC, U.S. Department of Energy (DOE) , and SCO
  - Covers the Microreactor Research, Development, and Demonstration
  - Defines NRC's regulatory role
- SCO requested NRC review of the risk-informed methodology
- NAC will request a transportation package review to support SCO Project Pele activities.
- U.S. Department of Energy (DOE) is the authorizing official for Demonstration Project Pele Microreactor at Idaho National Laboratory
  - Reactor operations and transport onsite

Why a Risk Methodology?

- Leak rate and dose rate requirements (10 CFR Part 71.51(a)) after hypothetical accident conditions (10 CFR 71.73)
- Regulatory approval pathways
  - Alternate test criteria in 10 CFR 71.41(c)
  - Exemptions (10 CFR 71.12) from specific requirements using a risk-informed approach

Risk-informed Methodology

- First-of-a-kind transportation risk assessment of an irradiated microreactor to evaluate
  - Accidents
  - Dose to member of the public and worker
- Leverage current risk-informed and performance-based concepts to evaluate future specific exemptions
- NRC's review
  - Evaluates risk associated with microreactor transportation
  - Identifies important scenarios that drive the risk
    - Informed by design of components
  - Identifies the need for compensatory transportation measures during transportation

Risk Assessment Approach

- Risk evaluation guidelines defined by pairs of likelihood-dose thresholds
- Elements of the Probabilistic Risk Assessment
  - Identification of Safety Functions
  - Characterization of hazardous conditions to identify accidents
  - Determination of accident likelihoods
  - Consequence analysis
  - Evaluation of probabilistic risk assessment results against risk evaluation guidelines
  - Sensitivity Studies
  - Uncertainty Analysis
  - Defense-in-Depth

Risk Evaluation Guidelines

- Pairs of likelihood-dose are informed by existing NRC performance criteria for nuclear fuel facilities, DOE nuclear facilities, and International Atomic Energy Agency risk evaluation guidelines
- Surrogate values that align with NRC nuclear safety goals, quantitative health objectives (QHO) and corresponding proposed quantitative health guidelines (QHG)

Risk Evaluation Guidelines

- Pacific Northwest National Laboratory (PNNL) proposed using QHGs that are based on the NRC report titled, “Risk-Informed Decisionmaking for Nuclear Material and Waste Applications”
- QHGs are based on the QHOs from the 1986 NRC Safety Goal Policy statement developed for the operation of nuclear power plants
- Consistent with similar risk-informed performance-based approaches endorsed by NRC in Regulatory 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, Certification, and Approvals for Non-Light- Water Reactors”

Proposed Risk Evaluation Guidelines for the Public

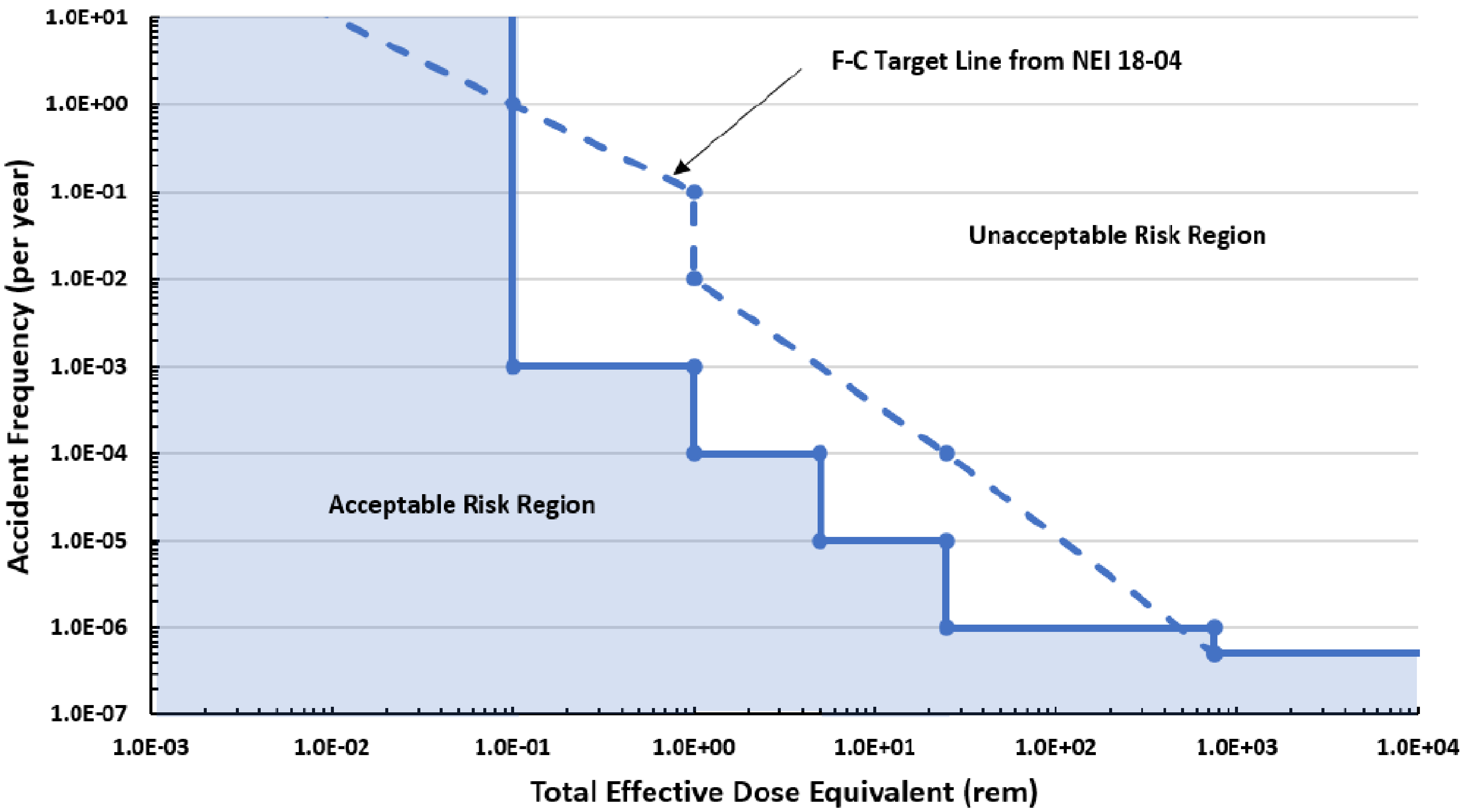


Figure 4.7. Proposed Offsite Public Risk Evaluation Guidelines Chart for Transport of a TNPP Package

Proposed Risk Evaluation Guidelines for Workers

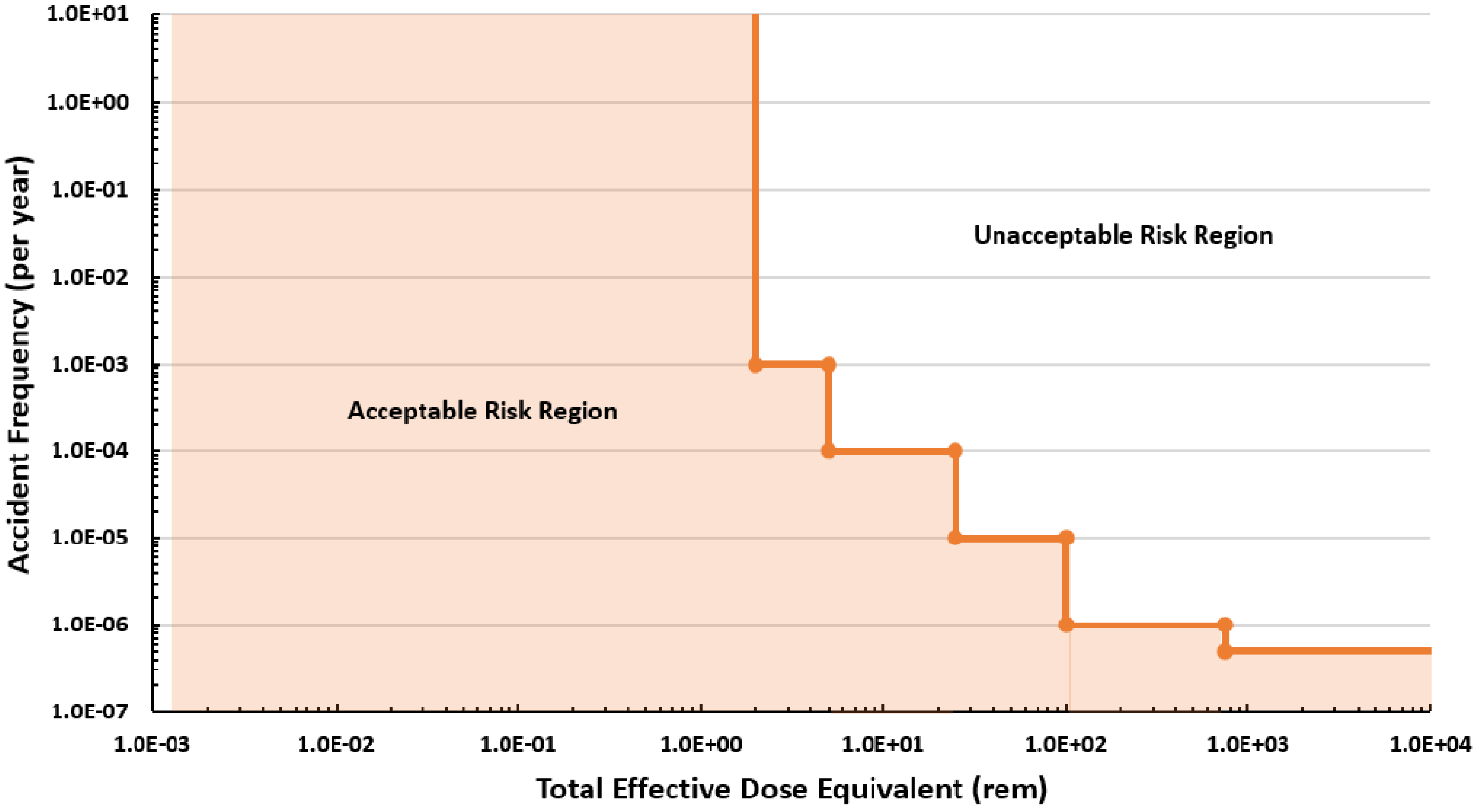


Figure 4.8. Proposed Worker Risk Evaluation Guidelines Chart for Transport of a TNPP Package

Proposed Risk-Informed Methodology Review Process

Initiating Event

- Identification of Hazardous Conditions
- Identifies bounding representative accidents by phenomena
- Estimates likelihood of occurrence for bounding accidents

Proposed Risk-Informed Methodology Review Process

Accident Sequence Analysis

- The Methodology is an approach for determining the risk for a transport of a micro-reactor package
- The Methodology estimates damage based on expert judgement
- Numerical assumptions and results in the Methodology are unimportant to understanding the approach
- Package application should include structural and thermal analyses to evaluate damage to the package

Proposed Risk-Informed Methodology Review Process

Source Term Analysis

- Nuclide inventory based on expected operations and cool time
- Two phase screening based on quantity and A_2 value
- Material available for release
  - Material that migrates out of the tri-structural isotropic (TRISO) fuel
  - Activated reactor components
- The Methodology proposes to use the DOE handbook "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities"

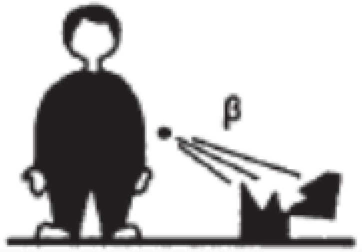
Proposed Risk-Informed Methodology Review Process

Consequence Analysis

- Considers four dose pathways from the Q-System along with neutron dose (excludes submersion in a cloud)
- PNNL states that neutron dose is usually a fraction of the photon dose
- NRC experience is that neutron dose can be a significant contributor where there are areas of dense gamma shielding

Dose Pathways in the Q-System per IAEA SSG-26

Direct Photon Dose



Direct Beta Dose

Inhalation Dose

Submersion in a Gas Cloud for Noble Gasses

Skin Contamination and Ingestion Dose

Specific Safety Guide No. SSG-26 (Revision 1), “Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition)”

Proposed Risk-Informed Methodology Review Process

Uncertainty Analysis & Defense-in-Depth

- Process addresses key assumptions and sources of uncertainty
- Sensitivity studies supports identification of controls and compensatory measures to reduce risk
- Application of defense-in-depth and safety margin philosophies consistent with NRC guidance and policy

Next Steps

ACRS Full Committee

December 6, 2023

Issue Commission Paper (Information)

January 2024

Methodology approval needed by NAC in January 2024

Pre-application Engagement with NAC

First Quarter 2024

Receive NAC Package Application

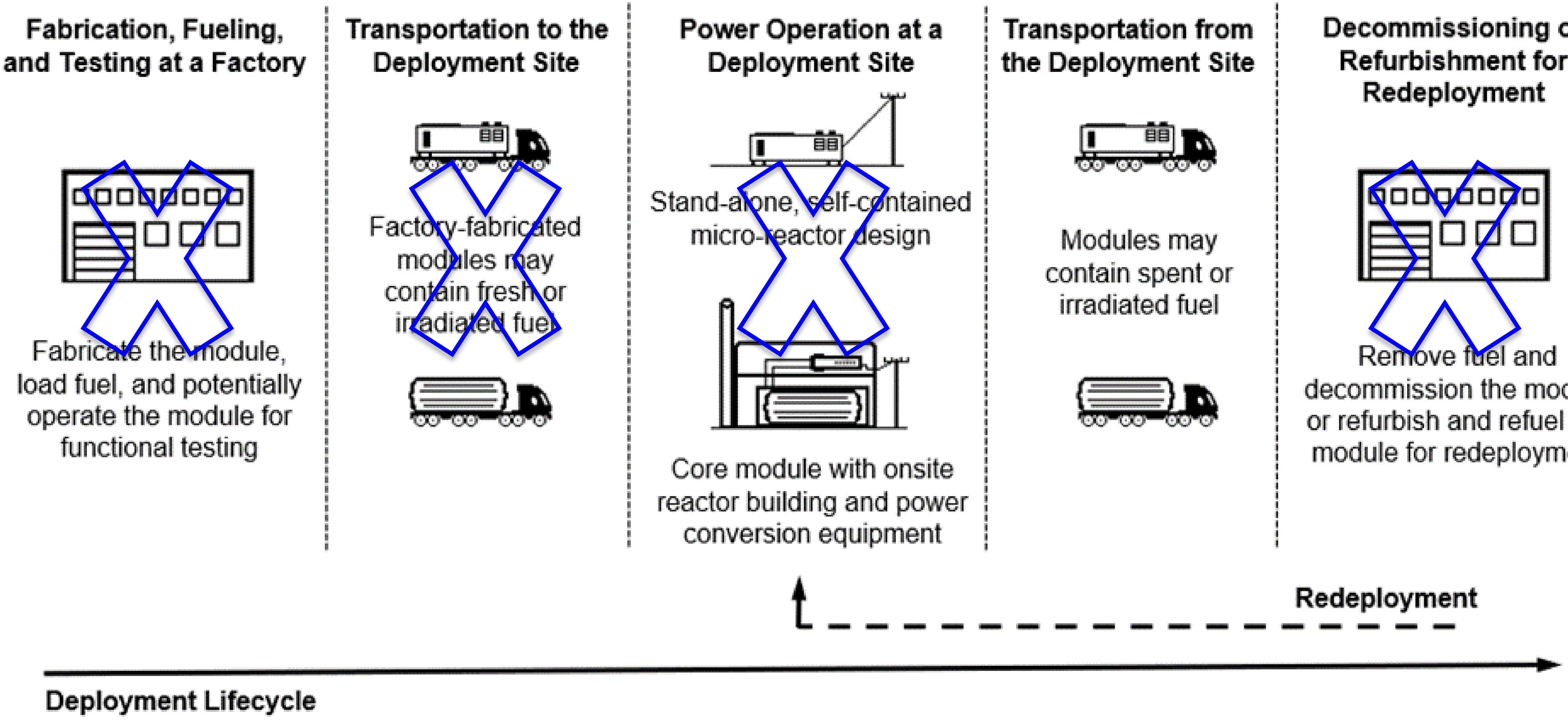
Fourth Quarter 2024

References

- PNNL Methodology:
  - “Development and Demonstration of a Risk Assessment Approach for Approval of a Transportation Package of a Transportable Nuclear Power Plant for Domestic Highway Shipment” (ML23268A331)
- Draft NRC Staff Evaluation:
  - “Development and Demonstration of a Risk Assessment Approach for Approval of a Transportation Package of a Transportable Nuclear Power Plant for Domestic Highway Shipment” (ML23296A083)

Backup slides

Focus of Risk Method Supporting Project Pele Transportation



Fabrication, Fueling, and Testing at a Factory

Fabricate the module, load fuel, and potentially operate the module for functional testing

Transportation to the Deployment Site

Factory-fabricated modules may contain fresh or irradiated fuel

Power Operation at a Deployment Site

Stand-alone, self-contained micro-reactor design

Core module with onsite reactor building and power conversion equipment

Transportation from the Deployment Site

Modules may contain spent or irradiated fuel

Decommissioning or Refurbishment for Redeployment

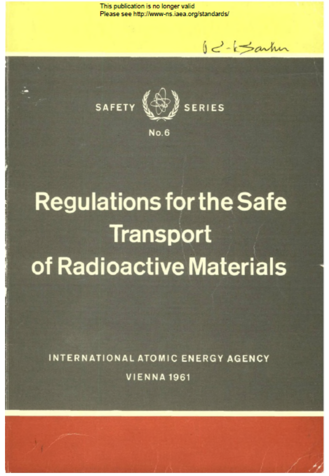
Remove fuel and decommission the module or refurbish and refuel the module for redeployment

Redeployment

Deployment Lifecycle

Overview of International and Domestic Regulations

- International Atomic Energy Agency (IAEA) transportation standards are developed by consensus by the **TRAN**sportation **S**afety **S**tandards **C**ommittee (**TRANSSC**)
  - First standards published by the IAEA in 1961
  - By 1969, many Member States adopted the standards as the basis for their own regulations, including the United States
  - Applicable to domestic and international transport of radioactive material by all modes of transport
- Specific Safety Requirements No. SSR-6 (Rev. 1) provide standards for all package types, including [Type B and fissile material]

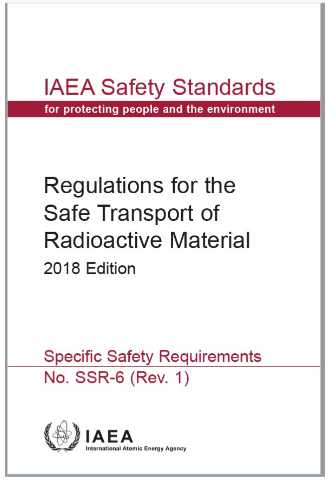


This publication is no longer valid
Please see http://www-ns.iaea.org/standards/

SAFETY SERIES
No.6

Regulations for the Safe Transport of Radioactive Materials

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA 1961



IAEA Safety Standards
for protecting people and the environment

Regulations for the Safe Transport of Radioactive Material
2018 Edition

Specific Safety Requirements
No. SSR-6 (Rev. 1)

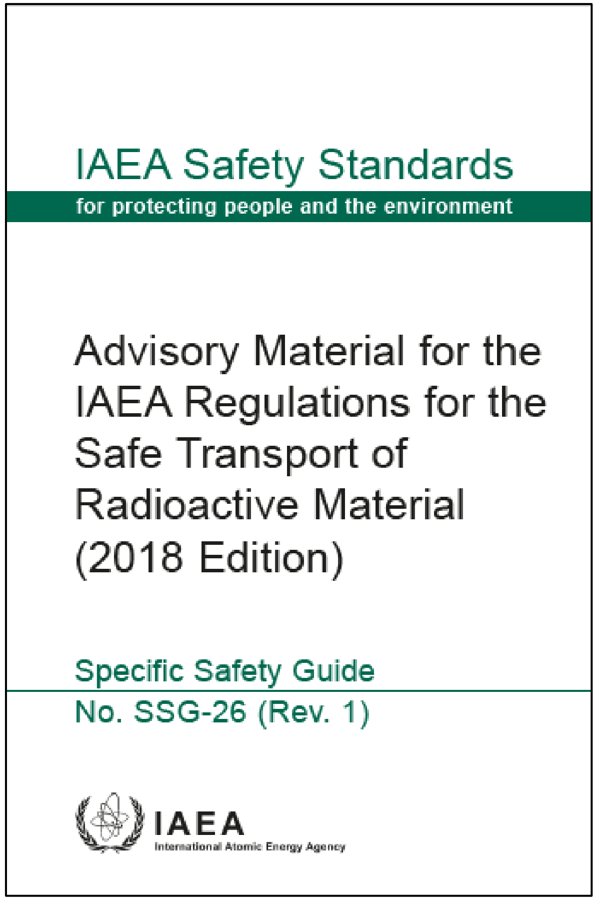
IAEA
International Atomic Energy Agency

A Method to Define A Values

- Prior to the Q-System, radionuclides were:
  - – Categorized into seven transport groups and
  - – A "special form“ group
- “Normalizes” radioactivity based on radiation risk
- Establishes basic radiological quantity for transport
  - A values delineate between Type A and Type B packages*
  - A_1 is for special form material
  - A_2 is for normal form material

Regulations and Guidance for Package Approval

- Advisory material is in IAEA’s Specific Safety Guide No. 26 (SSG-26)
- Q-System was introduced in 1973 IAEA regulations (Annex 1, SSG-26).
  - It determines the activity limits for each radioisotope (i.e., A_1/A_2 values)
- “A” Values were codified in NRC and DOT regulations in September 1983 (48 FR 35600 and 48 FR 10218, respectively)



IAEA Safety Standards

for protecting people and the environment

Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition)

Specific Safety Guide

No. SSG-26 (Rev. 1)

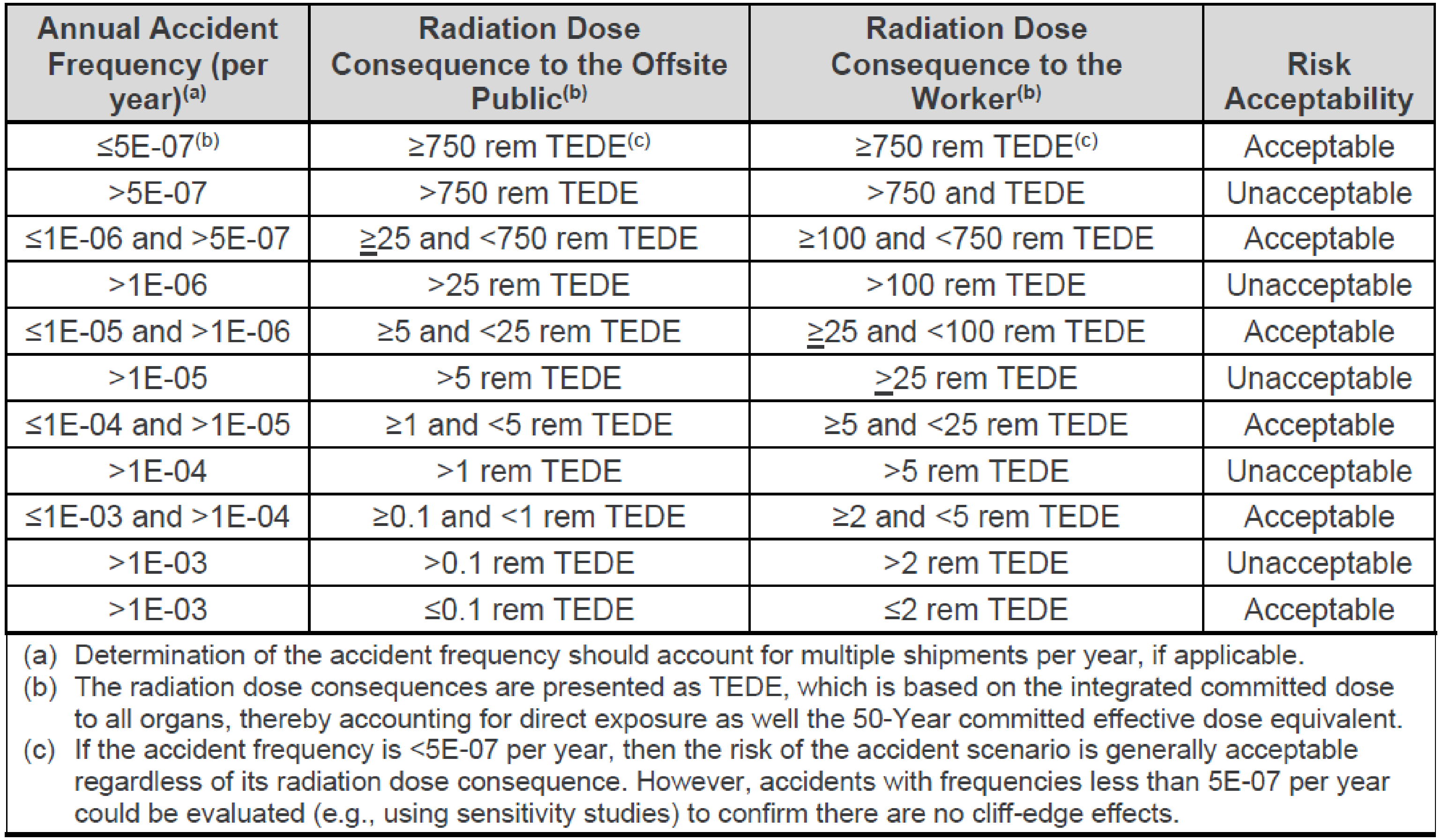
IAEA

International Atomic Energy Agency

Risk-informed Methodology

Risk Evaluation Guidelines

Table 4.7. Proposed Radiological Risk Evaluation Guidelines



Annual Accident Frequency (per year)(a)	Radiation Dose Consequence to the Offsite Public(b)	Radiation Dose Consequence to the Worker(b)	Risk Acceptability
≤5E-07(b)	≥750 rem TEDE(c)	≥750 rem TEDE(c)	Acceptable
>5E-07	>750 rem TEDE	>750 and TEDE	Unacceptable
≤1E-06 and >5E-07	≥25 and <750 rem TEDE	≥100 and <750 rem TEDE	Acceptable
>1E-06	>25 rem TEDE	>100 rem TEDE	Unacceptable
≤1E-05 and >1E-06	≥5 and <25 rem TEDE	≥25 and <100 rem TEDE	Acceptable
>1E-05	>5 rem TEDE	≥25 rem TEDE	Unacceptable
≤1E-04 and >1E-05	≥1 and <5 rem TEDE	≥5 and <25 rem TEDE	Acceptable
>1E-04	>1 rem TEDE	>5 rem TEDE	Unacceptable
≤1E-03 and >1E-04	≥0.1 and <1 rem TEDE	≥2 and <5 rem TEDE	Acceptable
>1E-03	>0.1 rem TEDE	>2 rem TEDE	Unacceptable
>1E-03	≤0.1 rem TEDE	≤2 rem TEDE	Acceptable

(a) Determination of the accident frequency should account for multiple shipments per year, if applicable.

(b) The radiation dose consequences are presented as TEDE, which is based on the integrated committed dose to all organs, thereby accounting for direct exposure as well the 50-Year committed effective dose equivalent.

(c) If the accident frequency is <5E-07 per year, then the risk of the accident scenario is generally acceptable regardless of its radiation dose consequence. However, accidents with frequencies less than 5E-07 per year could be evaluated (e.g., using sensitivity studies) to confirm there are no cliff-edge effects.