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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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RELIABILITY AND PRA SUBCOMMITTEE

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WEDNESDAY, MARCH 5, 2014

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ROCKVILLE, MARYLAND

The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 8:30 a.m., John W. Stetkar, Chairman, presiding.

COMMITTEE MEMBERS:

JOHN W. STETKAR, Subcommittee Chairman

RONALD G. BALLINGER, Member

DENNIS C. BLEY, Member

MICHAEL L. CORRADINI, Member

HAROLD B. RAY, Member

JOY REMPE, Member

MICHAEL T. RYAN, Member

STEPHEN P. SCHULTZ, Member

ACRS CONSULTANT:

WILLIAM SHACK

DESIGNATED FEDERAL OFFICIAL:

JOHN LAI

ALSO PRESENT:

EDWIN M. HACKETT, Executive Director, ACRS

THOMAS BOYCE, RES

ARTHUR CUNANAN, RES

JOHN KAUFFMAN, RES

MARTY STALLONE*

MARTIN STUTZKE, RES

BRIAN THOMAS, RES

*Present via telephone

T-A-B-L-E O-F C-O-N-T-E-N-T-S

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P R O C E E D I N G S

(8:30 a.m.)

CHAIRMAN STETKAR: The meeting will now come to order. This is a meeting of the Reliability and PRA Subcommittee. I'm John Stetkar, Chairman of the Subcommittee meeting.

ACRS members in attendance are Ron Ballinger, Harold Ray, Steve Schultz, Dennis Bley, Mike Ryan, Joy Rempe, and Mike Corradini. We're joined also by our consultant Dr. Bill Shack. John Lai of the ACRS staff is the designated federal official for this meeting.

The Subcommittee will hear a brief presentation of the Generic Issues program. We'll also discuss the scoping estimates of the multi-unit site risks analysis. There will be a phone bridge line. To preclude interruption of the meeting the phone will be placed in a listen in mode during the presentation and committee discussion.

We have received no written comments or requests for time to make oral statements from members of the public, regarding today's meeting. The subcommittee will gather information and analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full committee.

The rules for participation in today's meeting have been announced as part of the notice for this meeting, previously published in the Federal Register. A transcript of this meeting is being kept, and will be made available as stated in the Federal Register notice.

Therefore, we request that participants in this meeting use the microphones located throughout the meeting room when addressing the Subcommittee. The participants should first identify themselves, and speak with sufficient clarity and volume, so that they may be readily heard. We'll now proceed. And I call upon Tom Boyce of the NRC staff. Do you have any opening comments?

MR. BOYCE: Well, good morning, I guess. We work in the Generic Issues branch, and we think we do a great job. And we are happy, actually, to have had the opportunity to have an article published inside NRC on this particular topic, where we screened out the multi-unit risk.

And as a result of that article we came to light, we got noticed. And I think we really welcome the opportunity to be able to tell you about what we do.

CHAIRMAN STETKAR: Thank you for that. I don't know who's going to take the lead. John?

MR. KAUFFMAN: Good morning. My name is John Kauffman. I'm the program lead for the Generic Issues Program. To my left is Marty Stutzke, who is going to be briefing on the notational analysis that he developed. And over on the far left is Arthur Cunanan, who's a Generic Issues staff member.

As Tom already mentioned, this issue has received some attention from outside, in an inside NRC article. And also the Union of Concerned Scientists has been critical of our screening out of this issue, based on the Fukushima event.

The staff initiated this issue. It was proposed by the SOARCA staff in research. And it became a proposed Generic Issue in 2008. At that point in time what did we know? We realized that there are no legal requirements for single unit PRAs. We realized that there were no multi-unit PRAs. So it would be very difficult to get information on this issue based on that.

We also had the understanding, or the thought that this topic is mostly driven by external events that could affect both units. And we had a Generic Issue underway on Generic Issue 199 on seismic. And soon thereafter we had an Issue that became, on flooding that became GI-204.

And we also knew that it would be a major effort to develop multi-unit PRAs. And it didn't seem like there was justification to push the industry that way. And it wasn't even clear that there was, could be justified to spend this type of resources in research to develop that.

So this was a topic that the Generic Issues program staff initially felt would require longer term research to be understood. And one of our criteria is, topics that aren't really understood, and that will need longer term research, should not become Generic Issues. They should become research projects, or perhaps not pursued at all.

Anyway, the research management in place at the time decided to exercise the program to develop agency wide consensus on what to do with this issue. So this issue was accepted and it went to screening.

The screening panel was made up of three members. Sunil Weerakkody was the panel Chair, Don Budde from New Reactors was a member, and Marty Stutzke was also a member. And as the issue progressed the screening panel came back. And they also recommended that it not be a GI.

But research management kept pressing us about, is there something we can do? Is there some sort of a bounding analysis that we can do to show that the risk is low, and that this isn't a topic that needs to be pursued quickly? And so, we continued to work as a panel and engage.

Then real life intervened. Fukushima happened. And much of the staff was redirected in responding to that. In fact, I went to JLD for about eight or nine months. This issue sat in limbo for a little while.

But remember, as I talked about, it would be a major effort and take time to develop the multi-unit PRAs. So it was a case of, I don't think the delay was harmful. Next slide, please.

As a very brief overview, we're moving to a three stage Generic Issue Program. I briefed the full committee about three years ago. And at that point there was a five stage program. Since then there's been a tiger team to improve the program.

And it's been decided that the identification and acceptance review stages could be eliminated. And the second stage in the current program, which is the technical assessment and regulatory assessment, which we're going to call assessment, could be combined.

And then typically when we have figured out what agency action needs to be taken with an issue, then it gets sent to the program office for implementation. And that was considered to occur outside of the program in the past.

With this revision that we're currently doing that stage will now be within the program. And, of course, the issue can exit when it fails the criteria, or it goes through additional research. Or this last flow, if it isn't really corrected. If it goes to another office for implementation, then it's still in the program. Next slide, please.

The program's criteria are basically set up that whatever we're dealing with can pass backfit. So the first criteria is it must pass, it must effect public health and safety. Virtually everything does that. So that has some embedded risk criteria in it. And basically, if we can show that the risk of something falls below ten to the minus fifth, then it would screen out.

Second criteria is that issues have to be generic. And we try not to be duplicative with other programs. So the third criteria is it's not readily addressable through established or existing programs.

And the fifth criteria, can have its risk or safety significance adequately determined. That gets to what I mentioned before, that if something needs a lot of work to understand it, perhaps it's appropriate for that work to be done.

But until we understand it, it's not something that we can justify taking action at the plan. And we want our issues to be defined and discrete. And ultimately, we want issues that will result in action by licensees.

An example there, and we go back to TMI. There was a Generic Issues that headquarters staff be consolidated in one building. Now that is not something that would effect licensees. So in today's program we would not take that as a GI. Because it's really, other than where licensees would send things, it's really not something in the licensees' purview. Next slide.

The crux of this issue is that multi-unit core damage sequences may challenge the ability of the plant operating personnel. They may require resources beyond those available for single units. And there's a potential for increase in offsite consequences.

And the third bullet kind of sums this up. To really understand what that means, and how important those issues are it would require quantification through development of a PRA.

And just as some background, there are 32 sites with two operating reactors. And there are three sites with three operating reactors. And in addition, there are some sites that are near to each other, like Nine Mile and FitzPatrick, and Salem and Hope Creek. Next slide.

As we talked about, the first script here in the program is a risk component. And the reason we're here today is that second bullet. Marty developed a highly simplified notational analysis. And this analysis, he'll get into it in gory detail.

But this analysis suggests that the currently operating plants meet the NRC safety goal policy for single units. And therefore, it appears that the risk of this topic is low. And it's a major justification for why there's time to perhaps pursue multi-units done on PRAs, and that interim regulatory actions are not needed.

The thinking of this issue also failed the fifth criteria. And the idea there is, we did use a highly simplified analysis to develop a belief, or a basis, that we don't think this is highly risk significant.

However, until you actually do a full blown Level 3 PRA for a number of sites, you won't absolutely know that. And that activity would take a long time. And so this potential issue also failed on the idea that it would require longer term research to fully look at and evaluate. Next slide.

So the bottom line is, going forward, in addition to Marty's analysis, we note that the near term task force from Fukushima has reduced multi-unit risk with some of their 2.1, 2.3 seismic and flooding walkdowns and evaluations, the actions for the flex equipment, looking at emergency staffing, and those sort of things.

And research staff is also continuing to pursue insights into multi-unit risk via the Level 3 PRA project. And staff is expecting to have results from that in 2017. And, as with all Generic Issues, if that project results in insights that suggest reopening this issue, then that issue can be reopened at that time.

So that is the result of the screening. If there are any questions we'll be glad to take them. If not, Marty's ready to talk about his notational analysis.

MEMBER CORRADINI: Can I ask about the last bullet, staff is continuing? So when you do this for the Level 3 project, are you going to include all four units, or just the two current units?

MR. STUTZKE: Just the two current units

MEMBER CORRADINI: The logic being, since there's going to be four there anyway?

MR. STUTZKE: No, the logic being, let's analyze what we have the detailed designs for, and adjusting risk assessment for.

CHAIRMAN STETKAR: Let me ask, John, something about process. ACRS typically is involved in issues that are raised to the level of a Generic Issue. We typically follow those and have briefings, if not more formal interactions.

Why is the ACRS not routinely involved in issues like this, and supporting analyses and decisions that are made to not pursue something as a Generic Issue?

MR. KAUFFMAN: The reason we're having this meeting is literally, we discovered it through, you know, a news item. And, okay, well I guess the short answer is the process isn't really set up for that.

And one thing to remember is, we get all sorts of things submitted to us. They can be more worried about nuclear safety. And so our process is set up so that some things we can dispose of, we don't spend a lot of time on, and can dispose of fairly quickly.

For the issues that do become GIs, we put out probably an internal reports on those issues, that are updated every quarter. And we also put out a periodic report on the status of proposed issues. That comes out about twice a year, once or twice a year.

So I guess part of it is we think it is set up for NRC staff and others to be aware, and weigh in on the issue if they want. Certainly it is something we can look forward.

As I said, we are redoing our management directive and our process. And it's out for comment. So certainly that is something you can comment on. And something we can take back and include on our MD rewrite and update.

CHAIRMAN STETKAR: I look at this as somewhat, from our perspective, from the committee's perspective, as something that's somewhat analogous to updating regulatory guides, for example. Different issues, but in terms of process.

We essentially receive information from the staff whenever a regulatory guide is updated. We look at the merits of the substance of the proposed update. And at that point we make a decision about whether or not we want to pursue it further, or we think it's primarily an administrative, you know, update, or something like that.

But at least we're given the opportunity.

There's a formal communication that informs us that there's activity afoot, if you will. And gives us the opportunity if we decide to weigh in or investigate it a little bit more deeply.

Essentially, it doesn't require the ACRS to cull through tons of information that's produced by the NRC staff every year, in terms of what's happening. And some of these issues could conceivably be more weighty than, for example, an administrative update to some regulatory guide.

So we may want to think about a more formal method of communication, to alert us when you do reach a decision about something. Certainly when something is raised to the importance of being a Generic Issue, we're informed of that. But, all right, these decisions that fly below the radar is, at least from our radar anyway.

MR. KAUFFMAN: Right. And we just had a realignment of the program. The program got moved from Research DRA to Research Division of Engineering. And Tom Boyce just happens to own the Reg Guide branch and updates. So I think it's a perfect opportunity for us to think about how to re-engage, or engage differently.

MR. BOYCE: Yes. If I could draw a parallel to the Reg Guide process? We give the opportunity to review draft guides. But it's a question of maturity. We develop initial staff positions to the point where we want to issue a revision and a draft guide, or new guidance and a draft guide.

And so really we need to bring an issue to an issue to a state of maturity before it's worthwhile talking about. And in this case we are in the screening process. So we had a panel that met, brought it to a state of maturity. And we issued a memorandum from the panel saying, here's our finding.

So at least in this one example, you're getting the information in an analogous manner when it's mature enough that we have an opportunity to weigh in. In this case we said, we don't want to take a position.

But we do, the next stage of the process is pass screening into assessment. And then during the assessment this might be a good opportunity for you to weigh in and review it. I would suggest we -- These memos are publicly available. And have your ACRS staff take a look at the ones we've recently issued.

And then maybe we can decide whether or not you'd like to review the types of issues we look at. But I would suggest after the panel meets and does the screening analysis, is the right level of maturity for that opportunity.

MEMBER BLEY: That would make sense. John, I'd like to take you back to your Slides 3 and 4, and ask a couple of questions. Because I haven't been following this all the way.

You said that the new revised three stage program here dropped off the first two steps, which were kind of the same as, described how things actually get to you, right?

MR. KAUFFMAN: Right.

MEMBER BLEY: Can you describe that process that's now a part of your program, to me? How do things get to you?

MR. KAUFFMAN: Things can be sent us, any member of the public can propose a Generic Issue. And also NRC staff members, as members of the public and as NRC staff, can propose issues. Although we do encourage NRC staff members to work through their chain of command.

And each office also has a contact, a person that's familiar with the Generic Issues program, that we ask them to work through. But they can be submitted via email, it can be submitted via memo.

MEMBER BLEY: Okay. But they come actually as effectively a letter saying, I propose this as a Generic Issue?

MR. KAUFFMAN: Yes.

MEMBER BLEY: So all of those go into this process that's on the chart here? Anything that shows up on your desk as a proposed Generic Issue?

MR. KAUFFMAN: Well, as I said, if it's something that is kind of frivolous like, I'm worried about nuclear safety, we work with the submitter and try to focus their concern on something that we can work with.

And it's a little bit of an art form as to when we might combine issues, and when we might separate issues. But, yes. The idea is that it's a very open program. And we document the results so people can see what has become of the issue.

MEMBER BLEY: There's a little informal front end where you work things out. But if whoever submitted the idea still wants it, it then comes into this program.

MR. KAUFFMAN: Right. It comes in. And a big part of working with them there is, we know the criteria, we know the type of things that will cause it to fail. And so we work with them to try and develop wording or justification, such that it doesn't fail.

We also do a review for duplication. Throughout the history of the program there's been about

850 issues. And if somebody re-proposes an old issue we will try and identify that, and see if anything has changed that would justify re-opening or a different conclusion.

To answer your question, the new version of the management directive will talk about the criteria, identifying and submitting issues. We're just not calling that a stage. And what we called acceptance review in the past, which was at a low level, the branch chief could say, it clearly doesn't meet the criteria, we're not going to accept it.

There is still going to be a provision in the screening that if it clearly doesn't meet the criteria that it can be closed out at that point. In many ways this three stage process is -- People were confused by the five stages. So this is being helpful.

I would say a major change that isn't on this slide is, the current program, when something passes screening and gets to communications plan, it gets to public meeting, and it gets designated as a Generic Issue.

The new program, it will not become a GI until the assessment is completed, and the agency is deciding to take action. So in the future, GIs will not be a thing where the agency might be taking action. They will be things where the agency has decided.

MEMBER BLEY: Already moves through assessment, and is implemented as a GI. Can we go to the next slide? Some of these, and I haven't ever followed your process. Some of these seem a little sticky to me.

I mean, Item 1, it must effect public health and safety. And you said that is the core damage risk of ten to the minus fifth per year or higher, I think is what you said.

MR. KAUFFMAN: Right.

MEMBER BLEY: But in Item 5 somehow you've already decided the risk up in 1. And then we come to 5, that you must be able to adequately determine the risk. But you're actually using that in 1. So they seem a little confused.

MR. KAUFFMAN: Well, I think one way to look at this is, the criteria -- As an issue works through the process we learn more about it. And I think, and at any point it's determined that it's failed these criteria, then the program can decide that it's not a Generic Issue, and then stop dealing with it.

So the first one, at least initially, is the topic must kind of have the potential to be a big safety issue and deal. And later on in 5, once we determine its significance, if at that point we think it can't pass backfit, then we don't really have a choice. Our hands are tied, and we have to move on.

So 5 in a different wording might be, is this something we understand? Or is this going to take long term research? Because as you're probably aware, one of the historical, or one of the criticisms for a long time of the program has been that it's not timely in handling issues.

MEMBER BLEY: Some of the, for long term research issues, yes.

MR. KAUFFMAN: Yes. And so one way we've tried to address that is, if the thing is, you know, Brian Sheron has told me on many occasions, if something is a bonafide safety issue we want to work it, we want to deal with it, and move on.

But things, you know, true safety issues shouldn't take 20 years to work on. So part of that solution is, if it's going to take longer term research, we're just not going to call it a GI.

MEMBER BLEY: Okay. Well, my last question on the structure of how you do things. Well, my second to last question is, something comes in, it goes through your screening and assessment, and you decide it should not be a Generic Issue. What mechanism defines that? Is there memo to file or, you know, what is the resolution?

MR. KAUFFMAN: Actually, the way the process is set up is, all of the effected office directors are on concurrence for that panel memorandum. And Brian Sheron, as the executive sponsor of the program, he has to agree and endorse on that recommendation.

MEMBER BLEY: It's an executive memorandum essentially from research?

MR. KAUFFMAN: Right. With concurrence by the other offices.

MEMBER BLEY: By the other offices, okay. So there's a formal record of it?

MR. KAUFFMAN: Right.

MEMBER BLEY: And my last question is, the new way it's being rearranged. I think you said it's in a management directive that's still in draft. Is that right?

MR. KAUFFMAN: There's a management directive on the books. There's Management Directive 6.4. And we are revising that management directive and the associated research office instruction, Tech 002, that gives the detailed guidance on the program.

And as you're aware there's a, probably

aware, there's a fairly involved process to revise a management directive. It has to go, it has to be prepared. It has to go out to the offices, IG, EDO, ACRS, for comment.

And then we get the comments back, resolve the comments. And so the three step process I described is not the process on the books. But it's the process we're moving to.

MEMBER BLEY: Okay. That helps me.

MEMBER SCHULTZ: Does it envision then that the memo report is going to incorporate both the screening and assessment results? You mentioned that, it sounded as if there was present a couple of different streams of reporting assessment, and then screening memos. You said the screening memos might come out twice a year.

MR. KAUFFMAN: Well, at each stage --

MEMBER SCHULTZ: What do you envision with these --

MR. KAUFFMAN: -- there will be a memo that documents completion of that stage. Currently we put out quarterly reports on the status of all active Generic Issues. And we put out a report about once a year on the status of proposed issues.

MEMBER SCHULTZ: Once a year.

MR. KAUFFMAN: And those are available on the internal website, and also on the public website. We can easily enough give people those links, or show them where they are.

MEMBER SCHULTZ: Go back one slide. The proposed issue report is focused on screening? And you also have the exit approach associated with assessment.

I'm trying to understand, if we were to look for what comes out of the program, into the bottom box, through that exit path, is that going to be in the future one report? Or is it going to be something different?

MR. KAUFFMAN: What we will have is, we will have one report on the proposed issues, until they complete assessment. Although there will be a memo that comes out documenting the completion of screening.

MEMBER SCHULTZ: Separately?

MR. KAUFFMAN: Yes.

MEMBER SCHULTZ: Okay.

MR. KAUFFMAN: And of course, any pre GI report would have a link to that screening memo, and give the results of the screening in summary form.

MR. BOYCE: Maybe this would clarify it. I think you have a copy of the results of the screening memo for this particular issue. It's dated December 2nd. So what you're seeing is, at least where that first arrow comes down from the screening block, you're seeing the document, the staff documentation.

It's about a 20 page memo. And what it does is assess the project against the criteria. That's the first stage. And then it lets us seemingly add a different result when we accepted it into the program for further analysis.

We further developed the safety significance, and established more of the technical basis in the assessment process. And then developed potential options for regulatory implementation.

So the next report that you would see, which is the second arrow in the middle of that screen, coming down from assessment, would be a documentation of all that additional type of information, after the -- What I said before is, if you want to take a look at these type of memos, December 2nd, that's the right opportunity.

CHAIRMAN STETKAR: Yes, okay.

MR. BOYCE: Because we've made at least an initial call --

CHAIRMAN STETKAR: Yes. Because as this one, if they don't pass the screen they don't carry forward.

MR. BOYCE: Well, they don't carry forward in our program. The reason you might still want to review it is in case you thought the staff ought to pursue further research or --

CHAIRMAN STETKAR: Exactly, exactly. That's right.

MR. BOYCE: So the decision would be broader than just the Generic Issues program. It would be an agency level type decision that you'd be advising on.

MEMBER BLEY: But I think I agree that before it hits this point it's too amorphous for us.

CHAIRMAN STETKAR: Oh, yes. That's absolutely true. That's right.

MEMBER BLEY: Thank you.

MR. KAUFFMAN: Any other questions, so we can move on to Marty Stutzke's presentation?

MR. STUTZKE: Let's go for it. So I'm Marty Stutzke, the, well I'll give you the formal title, Senior Technical Advisor for Probabilistic Risk Assessment Technologies in the Division of Risk Assessment, Office of Nuclear Regulatory Research. And it's my, I guess whenever John --

CHAIRMAN STETKAR: So, okay, we can just call you Marty, right?

MR. STUTZKE: Yes. You can just call me

Marty. Whenever John gets these hard problems I find him sitting in my office, which is how I was introduced to this multi-unit Pre-Generic Issue.

As John had mentioned, the origin of the concern came out during the SOARCA sequence selection. It was actually identified by Rick Sherry. I'm certain most of you know Rick. And he was looking at sequences at a few of the plants. And the staff's PRA, not the staff's, but the licensees' PRA staff said, you know, this is a multi-unit accident. And he goes, huh, how about that.

So a long debate ensued within the SOARCA project about, maybe they should just analyze the effect of the multi-unit, by tricks such as doubling the source term, or something like that. Ultimately they decided not to pursue that. And hence, the motivation not to lose the concept to enter it into the Generic Issues program.

This has been, as John had noted, some time in evolving. Certainly I need to thank Rick, in addition, for raising the problem. Thank Brian Sheron for demanding that it be answered to an appropriate level.

Many discussions with my former Deputy Division Director, Doug Coe, on the idea of a notional model. And some discussions with Nathan Siu and Steve Lowers, my fellow SOSers, who did all the mathematics review for me.

I'll point out, this notional model is being presented at the PSAM Conference in Honolulu this summer. So, Honolulu sounds good right about now. Like that. So, flipping through briefly. I'll try to give you a little background here.

We'll talk about sequence delineation in a multi-unit environment. I don't know. All good presentations require some math. And so you've got mine for probably the next five years, and some example estimates like that. So, what the frontispiece, you know, the quote from Box and Draper about all models being wrong, but sometimes they're useful. Bear that in mind here, like that.

I should also point out, one of the other things that I do in life is that I'm the task leader for the multi-unit part of the Site Level 3 project that the Office of Research is doing. So I've been thinking about this from a broad viewpoint of how we can modify existing event tree, fault tree methodology to treat multi-unit risk, in addition to this notional model that came up.

Okay, Slide 11. We'd talked before about how many sites are actually multi-unit. And this is my list. Like that, we'll point out, you know, there are always the odd duck situations, you know, adjacent sites, like Salem, Hook Creek, and Nine Mile Point and FiztPatrick that are physically together, but they're actually separate units.

You'll see why that's important. The physical proximity is important for things like external events. So one would expect a seismic event would not just effect Hope Creek, but Salem would also feel it, things like that.

At the same time, if we're worried about multi-unit risk that is due to shared systems, you know, a lot of plants have interconnections like this. Then within Salem 1 and 2, one would expect that type of effect. But perhaps not between the Salem units and Hope Creek Point. Okay. And of course, excluding the new units being built at Summer and Vogtle. And exploiting the units at San Onofre. Okay.

So Slide 12. Let's be clear, when I talk about site risk, I'm talking about the accidents that effect one or more sources on the site. The typical PRA looks at one radiological source, for example, the reactor core, Surry Unit 1, or Surry Unit 2, et cetera, et cetera. And that's normally what we do inside a PRA.

And so we fixate on one source.

The issue here is, we could have multiple combinations of radiological sources being impacted, as happened at Fukushima. So looking at the types of radiological hazards on the site, we have the fuel inside the reactor, spent fuel that's stored in the pools, or dry cask.

And so in principle we would like to be able to address all combinations of that type of things with the -- That's exactly what we're doing in the Site Level 3 project. Or at least that's our intention.

And it is not just considering when the reactor is operating, but during various shutdown and low power states of operation. So Unit 1 could be operating, Unit 2 could be in refueling, and some sort of accident occur. And we will try to pick up all of the sorts of things like that.

As you can imagine, it becomes an enormous bookkeeping problem to try to keep track of that. Other people have suggested various approaches, you know. One I'll call the naive approach. They say, well, I know the single unit risks, I'll just multiply it by the number of units and I'm done, right? Well, I wish it were that easy, like that.

So the idea of a notional model comes out, as John had mentioned before, you know. When we do a Generic Issue assessment the general guidance is, pick a representative plant. Well, it's hard to pick a representative plant when you're talking about multi-unit risk. The external hazards are different. The seismic hazard varies from site to site. The units differ in the amount of their interconnections, you know.

An example of a highly interconnected system is at Browns Ferry, where a lot of systems are shared. At the Site Level 3 project we picked Vogtle. And the committee's previously heard why we ended up with that. In my perhaps sarcastic view of the world, Vogtle got picked because they were the ones that raised their hand, like that.

But we're finding at Vogtle is that it does not share many systems from unit to unit that are important to safety. So just to pick a single unit, and to, or a single site, and to be able to do a detailed Site Level 3 PRA, gives us insights about that site, gives us insights about methodology. But it's hard to extrapolate the results, and make a broad claim that no site has an issue like this.

That being the case, when I was first approached to do this, you know, I said, fine, you know, give me X million dollars and I'll be back in 20 years, and we'll have the answer.

MEMBER CORRADINI: You really did that, huh?

MR. STUTZKE: Not acceptable. Well my first attempt was --

MEMBER CORRADINI: What are you, some sort of researcher or something?

MR. STUTZKE: Yes, well, what can I say, like that. So the idea is, can we do something with the results of the single unit PRA to scale it up, or to otherwise estimate total site risk? That's the premise here.

So simple view of a Level 3 PRA, and this is highly simplified, is we have some initiators that come in, and we do a plant response, the so called Level 1 analysis that decides whether core damage has occurred or not. We will then, if core damage occurs, go into the containment response, the Level 2 portion of the analysis.

And basically you get three types of results, you know, where everything's okay. You might have a core damage, but there's no release. Or you have a core damage and subsequent release. And so, to estimate the risk after all of this high powered math, event tree, fault tree logic, the mean risk turns out to be the frequency of accidents, sequences times their consequence, and add them all up. Not that simple.

Now, thinking about it in a multi-unit environment, we have to realize that any sequence may cause an initiating event in the other units at the site. For example, one could imagine an initiating event that occurs, say at Unit 1, say a LOCA. And Unit 1 behaves as expected. And the effects of that LOCA are mitigated, and there's no core damage.

At the same time the other units will see perhaps a consequential loss of offsite power, due to the drop of load when Unit 1 went down. Now they're the ones being challenged. So it's inappropriate simply to focus on extending the core damage sequences for one unit into the other units.

You have to worry about these success paths of the event tree, that could also serve as initiating events for the other units, like this. And of course, floating around here is the need to consider the dependency among all the units, the shared systems. Those are the most obvious ones.

Common cause failures now cross the units like this. And, you know, perhaps the hobgoblin, as Doug True has called it, is the human actions floating around.

As we have mentioned before, you may overwhelm your available resources when the accident occurs. It's one thing to have an accident at 9 o'clock on Monday morning. And it's totally different if it happens at 2 o'clock Sunday morning. But just from numbers of people available, like this.

Also, a practical limitation is that when we do these things is, we don't always know individual sequences. We don't have all of the parts of the PRA. We generally get our high level results like this.

To remind you, the staff maintains SPAR models, the Standardized Risk Analysis that we use for various regulatory purposes. And the SPAR models normally are internal events at full power.

We have some SPAR models that cover external events up to Level 1. There are some proof of concept models that go to Level 2. And there are no Level 3 SPAR models. Instead what we have are older studies, such as NUREG-1150, that quite frankly have been, the details of them, the actual logic models are not as well preserved as one would expect or perhaps hope for.

So in thinking about this a lot, let's go to the next slide. If we're going to develop some sort of a notional, or a scoping model, one thing that stands out is there are different types of initiating events with respect to multi-unit risk.

So I've labeled them Common Cause Initiators. Something that challenges or trips all of the units at the site, basically at the same time, like a big earthquake. It could be a flood. Generally, some sort of external event. Perhaps a loss of grid transient, something like that.

And that's in contrast to what I will call Single Unit Initiators, or SUIs, that says one unit gets challenged. But it propagates over to the other units because of the shared systems, or some sort of spatial interactions, you know, a fire could propagate over, some sorts of common cause failures across the units, and operator actions.

An example of a spatial interaction is actually what happened at Chernobyl. When Unit 4 happened, the graphite moderator was ejected, and it landed on the roof of Unit 3, and actually set it on fire. Now, it didn't burn through, but it's an example of a sort of phenomenon that I'm looking for.

This distinction between the CCIs and the SUIs turned out to be a key realization of mine while I was developing the notional model. It let me then write some pretty tight mathematics that seemed to account for everything like this.

CHAIRMAN STETKAR: Marty, before you leave this, something that was nagging at me a bit as I read through this. How do you characterize initiating events that are loss of offsite power, loss of service water, loss of component cooling water?

MR. STUTZKE: It depends on the site. That's the problem.

CHAIRMAN STETKAR: No. In your math how are they characterized?

MR. STUTZKE: Generally, those are going to be Single Unit Initiators.

CHAIRMAN STETKAR: And you, well, we'll revisit that question later.

MR. STUTZKE: You know, actually, when you look at like the LOOP frequency that's in NUREG/CR-6890, and they actually calculate the probability of consequential LOOPs in other units.

And for loss of grid the probability is 0.8, it's not 1. It's not guaranteed to happen. Now, that may be because of the way that they've counted the data. It may be because you have different transmission lines.

CHAIRMAN STETKAR: It may be because they only counted things at power, and not during shutdown that effected the shutdown unit, for example. But that wasn't counted.

MR. STUTZKE: Right. The sort of thing like that. Okay. So with some nomenclature here we try to keep things reasonably clear like this, the number of units, the frequency of the Common Cause Initiators. These split fractions, the probability of release from k out of n units, are important.

The notional model can take a single unit accident sequence, and divide it up by adding split fractions. And then account for the likelihood of multiple are failed by doing that. And each one of those has, you know, consequences.

So along the way I found it useful to make the assumptions the units are in fact identical. This allows simple scaling, keeps the math clean. The other key assumption is that the consequence is proportional to the number of units involved, like this.

MEMBER BALLINGER: I have a question.

MR. STUTZKE: Yes.

MEMBER BALLINGER: What do you mean by identical? From a PRA point of view, how much identicalness do you need to be identical?

MR. STUTZKE: Well, it lets me say that the core damage frequency, or the release frequency at Unit 2 is the same number as it is for Unit 1.

CHAIRMAN STETKAR: Let me follow up on that. And I always like to use examples. Because it takes things out of the realm of philosophy. I used to be an operator at Zion Nuclear Power Plant. If you read the Zion Unit 1 FSAR, you would be led to believe that Zion Unit 1 had three diesel generators. If you read the Zion 2 FSAR you would be led to believe that Zion Unit 2 had three diesel generators.

In fact, if you went through the plant, Zion had five diesel generators. One diesel generator, depending on a relay race, either fed Unit 1 or it fed Unit 2. Now, those two units, in some sense, were identical, if you will. But their risk is not equal for loss of offsite power. The risk is very different.

So what I'd like to know is, did you look at the SPAR models to look at the success criteria for units that, especially units that had shared systems. For example, if you had a SPAR model for Zion, did the model for Unit 1 take credit for three diesel generators?

Or for Farley, take credit for four diesel generators? Or for Browns Ferry, take credit for four diesel generators and eight service water pumps, for those single unit events? If they did, your other unit risk is not equal to the first unit risk during those events.

MR. STUTZKE: Right.

CHAIRMAN STETKAR: And your combinatorics fall apart.

MR. STUTZKE: Right. I have looked at some of the SPAR models, not in the context of the notional analysis, but in the context of the Site Level 3, to try to understand.

And what you find in them as far as multi-unit aspects is, sometimes they credit recovery from the other unit, like this. And those are almost always set to zero in the model. So it's like a place holder in the model that's not credited whatsoever.

CHAIRMAN STETKAR: Okay. But in Zion it wasn't recovery. It was an automatic function. It was a relay race. At Browns Ferry it's not recovery, it's relays. So it's not an operator actively going out and mechanically switching things. It could be that people just said, well it's available to Unit 1, at Zion for example, with the reliability of the diesel.

MEMBER REMPE: Well also --

CHAIRMAN STETKAR: Instead of .5.

MEMBER REMPE: Also, when I was reading your Enclosure 1, like Peach Bottom's internal flood numbers, Units 2 and 3 have quite different numbers. And so I, that's just one example. One could also look at some of the other plants, like Limerick. And so I was puzzled, you know, why, you know, how good is that assumption?

And then of course, one thinks about what happened at Daiichi. And of course, the units were different. But sometimes the accidents did progress quite differently. And so I'm not, I mean, I know it simplifies the math. But is that a good assumption?

MR. STUTZKE: Well, I think as far as looking at individual units, what I did was pick the biggest one.

MEMBER REMPE: You did? Okay.

MR. STUTZKE: Picked the biggest risk, tried to bound it. Remember, the idea here is not to compute the risk. It's to show that the risk is below some level where we need to take immediate action. So we're trying to bound the risk like this. And I think that gives us a certain amount of latitude and flexibility in how we approach the problem.

MEMBER CORRADINI: So can I go down that path? Just so maybe I'm, maybe this is too simplified. Because I'm trying to find, there was a presentation given by Carl Fleming about this, in another context. I'm not sure if you were in the room. I think --

MR. STUTZKE: Yes, I listened to Carl's --

MEMBER CORRADINI: Okay. And I can't find it. But in my mind is, in the simplest form, as you had your, the one event tree I understood, which was like two slides ago. Don't go back.

It's that, if I have two units, and I have a common initiator, then at most the risk would double. Because I'd have twice as much source term for the same sort of effect. Is that wrong to think that way?

MR. STUTZKE: That's how we originally were thinking about it.

MEMBER CORRADINI: Okay. But is that bounding?

MR. STUTZKE: I don't think that's necessarily bounding.

MEMBER CORRADINI: Okay.

MEMBER REMPE: Because it could go longer.

MR. STUTZKE: It could go longer if you worry about these Single Unit Initiators. So I would have n units there, and each one of the consequences is times n. So that implies an n squared sort of term.

MEMBER CORRADINI: I was just thinking a multiplier.

MR. STUTZKE: Right. And that's why you'll see, when you get down to this you'll see both the n multiplier and the n squared multiplier pop out of the arithmetic.

MEMBER CORRADINI: Okay.

MR. STUTZKE: Which justifies your intuition about it.

MEMBER CORRADINI: But, so then to my first part of the question, you are familiar with some of the work I've seen by Fleming?

MR. STUTZKE: Yes.

MEMBER CORRADINI: Okay. Thank you.

MR. STUTZKE: Let's look at the Venn diagram on Page 16. This is trying to show how to account for the contributions of the multi-unit risk. So each circle is basically the result that you get from a single unit PRA. It's what we all know and understand, like that.

And the notion is that some of those sequences that are described in the single unit PRA, in fact could go on to create multi-unit sequences. So we could get two out of three, you know, specifically one and two, or one and three. We could get all of them coming in there, like that.

And the idea behind all of the math is to account for all of these different contributions like that. For example, when we go through the combinatorics we can express the single unit risk from Common Cause

Initiators, simply by adding up all the parts within one circle, within one part of the Venn diagram, like that.

In contrast, if I want to account for the multi-unit risk, I need to worry about all of the parts across all of the circles of the Venn diagram. That's the second equation there, after applying the assumption and adding them up, and you find the whole.

Or the site risk due to Common Cause Initiators, event units, is simply n times the per unit, or the single unit multiplier. That's where the assumption comes in about the units being identical. That's why you're allowed to say it's a factor of n times the single unit.

Otherwise you would come up with the sum of Unit 1 risk plus Unit 2 risk, for Common Cause Initiators. That sort of thing, like that. Okay. Single unit initiators are a lot harder.

Let's flip to Slide 18. And that's because you need to worry about the fact that some of those sequences in the single unit PRA that were successful, may serve as initiating events for the other units, like that.

So I've invented this taxonomy, that's caused no amount of confusion and consternation among the staff. These are my original labels, and I'm sticking with them. So we have the idea of a cascading sequence. That's just supposed --

At one time they were Type 1, Type 2 and Type 3. And I could never remember which one was which. So the idea here is a cascading sequence. Okay, I've got core damage in the unit where a Single Unit Initiator occurred, and also in one or more additional units, like that.

Propagating sequences are those that are success paths in the original unit. So nothing happened in the unit where the initiator occurred. But core damage and release occurs in other units, other additional units.

And then finally I needed a label for the restricted sequence. It says, it occurred in a specific unit, and it stayed there. It never got outside anyplace, like that. So to try to give you a flavor for, let's flip over to 19.

It looks very similar to what we saw for the -- Oops. The subscripts are on. That should be SUI subscripts, instead of CCIs. That is, the nomenclature's basically the same, except now I have a new factor in here that says I'm trying to account for the propagating sequences, like this.

Let's bounce to Slide 20, which is again the Venn diagram, and see if I can walk you through this thing. Yes, it's a guaranteed to cause eye strain sort of thing. You can draw it actually pretty eloquently, if there's only two units. And when you get three units it wants to become multi-dimensional, and things like that.

But here's the idea. If you start in the upper left you have a Single Unit Initiator. And we'll say that it occurs at Unit 1, realizing we could flip the diagram to say it occurs at Unit 2 or 3, or however many you want in there.

And the notion is, if you take the down branch to your restricted sequence, so only Unit 1 has core damage and a potential release. And that's the term for it that comes down here.

In addition, Unit 1 may go to core damage. And at the same time there may be core damage and release from the other units. And those are the so called cascading sequences, which I've labeled, the purple one, the white one, and the blue one in the diagram like this.

The new thought is the propagating sequences. So the success path sequences that come from the Unit 1, now serving as initiating events that can effect the other units. So the yellow part, the, I don't really know what that color is, and kind of the gray one down in the bottom.

MEMBER CORRADINI: So the yellow, fleshy and gray?

MR. STUTZKE: Right. Those are the propagating sequences.

MEMBER CORRADINI: So your point, your big point is, that I guess I missed, is that you can have something happen at Unit 1 and life is successful. But then something goes awry --

MR. STUTZKE: In Unit 2, or 2, or 3, or both. Yes. So just trying to be complete, and account for all of the parts later, like that. So using the nomenclature, before you end up with something like Equation 21, where the first part of the right hand side are some contribution from the restrictive and the cascading sequences.

The part on the right hand side are the propagating sequences, like this. Again, the assumption of identical units, that's the n multiplier on the right hand side. Otherwise, I would begin to have multiple turns like that.

So that's the key to making them the same like this. Pages and pages and pages of algebra later, flipping this thing around, you wind up with an expression that's shown on Slide 22. Nathan says I owe him big time for checking all of this, like this.

You end up with the equation at the top, where you see what we have done is, we have n squared now, times a single unit risk from the SUIs, minus a whole bunch of other terms like that.

MEMBER CORRADINI: So it's not n squared, but it's not n. It's somewhere in between.

MR. STUTZKE: Right.

MEMBER CORRADINI: And so, I'm sorry. You told me this once, but can you just repeat it? So one more time. It's n squared because --

MR. STUTZKE: I would --

MEMBER CORRADINI: it's a cascading effect?

MR. STUTZKE: The notion of n squared is, the consequence is now increased, because there's more units involved. And --

MEMBER CORRADINI: But it's not additive because why?

MR. STUTZKE: Additive in which sense?

MEMBER CORRADINI: Well, I'm still back to, my mind was going with your first explanation, which was on slide, don't go back, but on Slide, can't remember which slide it was, Slide 17. I was thinking, what, Slide 17 for everything. So this Single Unit Initiator is right for it. So one more time, then I'll stop.

MR. STUTZKE: The slide is for each initiating event that occurred, single unit, let's scale up the consequences by a factor of n. That accounts for the multi-unit force term that could come out. Then I realized I have n of those initiating events across the site.

MEMBER CORRADINI: Because it's, okay, we're back to the success of stopping it here does not necessarily propagate, correct?

MR. STUTZKE: Right.

MEMBER CORRADINI: Okay, sorry. Thank you.

MR. STUTZKE: So I end up with this expression. And on the right hand side you realize this is related to the propagating sequences. And the notion is, in order for a sequence to propagate and cause a problem it actually has to trip the other units in there.

And so, through this type of argument I think it's appropriate just to throw away the top side and bound it. So I end up with a compact expression of the square of the number of units times the single unit risk, as far as the SUIs.

CONSULTANT SHACK: And I had a problem with that, Marty. Because you're not really dealing with the same sequences in each one. You make the argument that there's a sequence probability and a conditional probability, you multiply them. You know, I'm willing to believe that those numbers are probably true.

But, you know, in your paper you make it seem as though it's logically, it has to follow that way. And it seems to me that you're not counting the fact that you could have different sequences leading to one versus the other. And therefore, that multiplication, the conditional probability isn't quite kosher.

MR. STUTZKE: Right. This isn't an account of individual sequences. This is a count of the total risk. So what it says is, I have a frequency coming out of Unit 1, times a split fraction that says, what is the probability that other units are involved, and this can go all the way to release?

And the argument here is the p term in here is, that is the probability given Unit 1 has gone to core damage. The q is given that it did not. Okay? So I believe there needs to be an additional term in here.

CONSULTANT SHACK: Right. But those frequencies are so different, that I don't see multiplying by the conditional probability then guarantees you have that relation.

MR. STUTZKE: When you look at the end of the PRA, the right hand side, right, the sum of the frequencies has to equal the initiating frequency coming up. You have that --

CONSULTANT SHACK: Okay.

MR. STUTZKE: -- right here. In other words, all an event tree does is split things out. It's a, you know, a classic probability tree diagram. And all it says is, all the parts have to equal what you put into it. So anyway, I'll press on. And then, I guess in the interest in time as much as anything. Yes.

But this is a crucial assumption that lets me bound this thing. Because it says, now I don't need to worry about the fraction that propagates and goes over like that. I can just discard it. And somehow I bounded it.

And when I throw it together, as shown on Slide 23, I end up with a rather compact expression for site risk, that says, well, it's less than the number of units times the CCI from single unit. Or, the square of the number of units times the single unit, right.

So this actually reproduces to some extent, you know, the naive estimator that would say, well, it's always due to some seismic event like this. And so all

I need to do is scale it up by n. And at the other hand it says, well, if I have single units initiators I increase the source term by a factor of n. And I have initiators across the site, okay. And so it works out.

Again, it achieves, the goal that we were after was, well, we can estimate this equation from the results of the single unit PRA. It all works out very well. The only thing that needs to be done is the protection results on the Common Cause Initiators and Single Unit Initiators. And generally we have that type of information available.

Of course, it's just a number. It's a very little insight as to what's driving the multi-unit risk. I think the best you can do is say, well, it's either common cause works the Single Unit Initiators like this. I have tried to evolve the technique into shutdown, low power, spent fuel.

And it's a God awful mess, to be honest with you. You end up with pages and pages of terms that don't want to cancel, or reasonably can be deleted, collapsed, whatever. So it's probably about, I've pushed it about as far as it can be pushed with this type of a notional analysis, like that.

So, having done this, let's reflect a little bit on what it all means, before we go looking at some of the numbers, like that. And that is simply, we don't have any guidance on what is acceptable site risk. And I've spent some time trying to drill down into the history of this thing.

When the safety goals were originally being formulated in the early '80s, remember they started out in basically 1981. And the safety goal policy statement wasn't published until '86. And there was a lot of, well say spirited discussion.

There were some meetings, you know, the notable one at Harpers Ferry. I think there was another one at Palo Alto a while back, like this. But one of the issues that the staff approached the Commission about was, what should we do about multi-unit sites? And the Commission came back and said, let's not worry about that now. We don't want to penalize multi-unit sites.

So the idea is, or the implication is that a multi-unit site could conceptually have a higher acceptable site risk than a single unit site. The Commission has been silent on how much higher that tends to be.

CONSULTANT SHACK: The Commission has been what?

MR. STUTZKE: They've been silent --

CONSULTANT SHACK: Oh, okay.

MR. STUTZKE: -- on what that is. So what we have now basically are single units safety goals. In addition, there was some work that went on for the so called technology neutral framework that Mary Drouin evolved. And we ask again, at the time it used to be called collective risk or integrated risk.

And the question is, how much risk is acceptable for a site when we lay this thing out? And again, what happened in that case was, the Commission told us to open an ANPR, we did, and Advanced Notice of Potential Rulemaking.

And we debated the issues like this. They came back after that and said, well, we will defer on this until we get an actual license application in hand for a multi-unit site, like the pebble bed, which hasn't happened. So we have yet to address this thing.

Again, the Office of New Reactors had a working group a while back, a couple of months ago, that I participated in. And again, the issue arose in the context of multi-modules. So now you're talking about small modular reactors. And you may have six, eight, ten of them on the site. And now, what to do?

The analogy I like to use, you know, is, a PRA will tell you how fast you're going. The

Commission's got to tell me the speed limit, okay. That's the policy. And we can debate, you know, about how accurate my measurement of the speed is, the notional things, or the details of the PRA.

But the question still remains, how much is too much? I would also hasten to point out, when we talk about safety goals, that they don't define how much is too much. They define how much is safe enough. It's at the lower end. It doesn't say how much risk is unacceptable.

Again, that comes into the realm of adequate protection. And there are no numerical guidelines that relate to adequate protection to risk metrics, like this. The best we have are some suggestions. And in our office instructions it's called LIC-504 that say, well, when the CDF begins to get up around ten to the minus three, think about shutting the plant down.

But the fact is, so we don't have anything for multi-units. So how to compare any numbers that I would be able to calculate and reach a decision? And all this says is, well, we could compare the site risk numbers that I produced to the per-reactor QHOs. And if we're below that, surely, we're okay, right. If we're not, then don't know what to do.

CONSULTANT SHACK: And you're in a gray

region.

MR. STUTZKE: Right. So I tried to make estimates of site risk for all of the multi-unit sites, by cobbling together the available information. And admittedly, it's pretty cobbled. For example, I told you before, we don't have a lot of external event SPAR models. There's maybe 16 or 17 of them in there, like that.

So I took some liberties by fitting it, you know, to the log normal probability plot, and tried to pick a big number, like the 80th percentile. And said, all I need to do to find a flood multiplier is to scale up the internal event CDF by a certain factor. That's the approach that's normally done in SAMA analysis for license renewals.

Similarly, I tried looking at NFPA 805 submittals to get an idea of where fire frequencies are. There are very few of them there. And again, I evolved some sort of fire multiplier, just to simply scale up the internal events. I had made estimates before from Generic Issue 199 on earthquakes.

And then there's new information out on the frequency of tornadoes. These are the tornadoes where the wind speed exceeds the designed site design basis, not necessarily the frequency of tornado induced core damage accidents. So it's pretty conservative I would say, like that.

I tried looking at a variety of, you know, frequency information's hard enough to find. Consequence information is almost nonexistent. There's NUREG-1150 that provides us some information like this. We have the benefit of the SOARCA analyses, that's perhaps better.

I persuaded one of my colleagues in DSA to do some scoping MACCS2 calculations for me, where basically where we're using the SOARCA input decks, and simply doubled the source term across the board, and re-ran it. And the results indicated, you know, the consequences of doubling the source term are less than twice, sub-linear or sub-additive, like this.

The problem with those types of calculations -- And I should point out, shortly after the Fukushima accident happened, Charlie Tinker and I, Charlie being one of the architects of the SOARCA study, got invited to brief the Chairman on multi-unit risk. And Charlie had sent Sandia, at work over the weekend, basically double the source terms.

MEMBER CORRADINI: He what? I'm sorry.

MR. STUTZKE: Yes, double the source terms and do a bunch of MACCS2 calculations for all of the

SOARCA things. And we went up there, and the Chairman was not satisfied with that.

Because, in true multi-unit accidents things aren't released simultaneously. One unit will release, and there may be a period of several times. The other is released, and now the wind has changed directions.

Meanwhile, at the start of the first release evacuation has already occurred. So maybe the second release doesn't effect anybody. Or, you know, has different effects like this. So the interplay of emergency planning, meteorology, and things like this.

So, you know, former Chairman Jaczko was not at all happy with this type of a simple let's double the source term sort of thing. But it does also indicate, you know, certainly as far as the health related metrics, individual latent cancer fatality risk, or whatever, the effect seems to be sub-additive, like this.

It gets even more complicated when you begin to use threshold types of models where there's no risk. And suddenly the multi-unit effect goes, wow, like this. So this is based, you know, realizing linear threshold is kind of at the heart of this sort of thing, which just may or may not be appropriate, like this.

Looking through all of these things I keep coming up with this conditional probability of latent cancer fatality. It varies between ten to the minus five and ten to the minus three. SOARCA was somewhere in the middle with ten to the minus four. It really depends on whether you're looking at seismic, or whatever.

So I said, look, let's just pick minus three across the board. It's probably the best I can do at this point in time. So the next slide shows you my attempt to quantify all of this, the internal event numbers, the flood multipliers.

So you can see where I've actually used the SPAR data, where I had an external event model, or NFPA 805. Those numbers are good. Otherwise I had to use this multiplier, like this. And anyway, so you come up with some estimate on the site individual latent cancer fatality risk.

And you scan down the list. And you see they're all below the two times ten to the minus six that we normally use for the quantitative health objective, like this. Not very much. I mean, if I rounded it, obviously I don't believe, I know this to be, you know, three significant digits.

MEMBER CORRADINI: Would I meet -- I know

I should know this, but I don't. You're comparing it to what? I'm back on Slide 24, but you don't have to go back. You're comparing it to the individual latent cancer fatality risk? Is that what you're comparing it to?

MR. STUTZKE: Right. Just that quantitative health objective, which turns out to be about two times ten to the minus six per year. The rationale here is SOARCA was telling us the individual early fatality risk was vanishingly small. So why compute it at a site level? Didn't seem to be worthwhile.

Actually, in regulatory analysis we don't use individual latent cancer fatality risk. We'll use things like population dose risk, person-rem per year, like this. Because that can be modified times the, you know, times the $2,000 dollars per person rem, or whatever the current number is. I understand it's been increased.

Or in regulatory analysis the other thing we use is offsite dollars, offsite economic consequences, like that. But again, there's no safety goal for single units for either one of those metrics. And I needed some yardstick to calibrate it against. So the only one that made sense was the individual latent cancer fatality risk.

MEMBER CORRADINI: And, I guess I should, again should note that's what I think. So that involves some assumption about evacuation, since you're --

MR. STUTZKE: It's all embedded into this conditional probability of latent cancer fatality number, up on Slide 25.

MEMBER CORRADINI: Okay.

MR. STUTZKE: That's where that comes from.

MEMBER CORRADINI: Okay. Thank you.

MR. STUTZKE: So in principle it's in there. But again, it's, I don't know to say that it's double counting, you know, the effect of this sub-linear like this. As I said before, it's possible when the first unit begins to release evacuation starts.

And so by the time a second or third unit would release, people have already left. In principle they've left. So that's where we ended up with this. It's, you know, for the purposes of screening or trying to disposition our Generic Issue to reach a conclusion, you know, do we have an immediate safety concern, yes or no? I think the analysis is probably sufficient for that purpose.

I've tried to introduce some, I guess as former Chairman Diaz used to call it, realistic conservatism in the analysis, to try to bound what I didn't know. That's not always a good approach in PRA, of adding conservatism. We pride ourselves on being realistic. But that's in the eye of the beholder.

MEMBER CORRADINI: I'm sorry, just one more clarification. You guys are going to ask all the hard questions. They're poised, ready. So simple, and back on Slide 22. So what you're computing here, or not 22, 23.

What you're computing here is the right hand side of the simple equation? So all we know is that assuming you did your estimates, it's less than the right hand side. But the listing of the tabular values is the right hand side?

MR. STUTZKE: Yes, correct. So when you look on it, it's broken into the single unit contributions and the common cause contributions. And it does add them up. So it's an effort to, you know, to try to estimate the entire site risk from all types of the initiating events.

MEMBER CORRADINI: Okay. Thank you.

MEMBER BLEY: Marty, a couple of things. One is, I really like the way you broke the problem apart. It's extraordinarily clever, and really interesting. When we come to actually applying it and get numbers for this table, is where I start getting quite nervous.

Number 1, and this gets to what John was saying earlier, the embedded assumption of identical units. I don't know how important that is. And it could be quite important. But Number 2, the way we've done the multipliers and used them makes me extraordinarily uncomfortable. The 80th percentile is picked out of the sky. I mean, there's no basis for that.

MR. STUTZKE: It is.

MEMBER BLEY: The reasons the multipliers vary very widely, which they do in the plants for which you have PRAs to compare, and the flood multiplier varies over orders of magnitude, and the fire over a really broad range.

And then we come back. We take the 80th percentile, and we apply it to all the plants, even the ones that have their own multipliers calculated --

MR. STUTZKE: Oh, no. No. That's --

MEMBER BLEY: That's what it looks like in the table.

MR. STUTZKE: No. If I actually had a value, I used it.

MEMBER BLEY: Okay. I thought I saw the other one there. Okay. That helps a little. Because I did see on one of these tables the generic multiplier.

But maybe I --

MR. STUTZKE: Yes. For example, so we have SPAR external event models for --

MEMBER BLEY: Oh, yes, I think you're right.

MR. STUTZKE: -- Salem.

MEMBER BLEY: Okay.

MR. STUTZKE: So I used it if I had it. You know, the question is what to do about the other sites where I don't.

MEMBER BLEY: But the 80th percentile doesn't help me very much. The reason the fire risk is wildly different is because designs are quite different.

MR. STUTZKE: Understood.

MEMBER BLEY: And there's a real basis for that variability. And we're not, we're kind of pretending using the 80th percentile accounts for that variability. And it's so broad. I don't find that comforting.

MR. STUTZKE: I would agree.

MEMBER BLEY: Now, on the other hand, as a quick look to say, do we have more work going on? And we can really understand this when we do a Level 3 PRA? Maybe that's a reasonable thing. But that's the quite queasy one.

MR. STUTZKE: Right. You know, the real problem is, you know, the premise, what this notional approach drives for is to let you use the results of the single unit PRA.

But we don't even have single unit PRAs for most of the plants, nor do the licensees. And, you know, trying to be a risk informed regulator, that puts us in quite of a dilemma.

CHAIRMAN STETKAR: Marty, I'm --

MR. STUTZKE: That's my indirect lobby for a PRA rule.

CHAIRMAN STETKAR: Marty, I want to --

MR. STUTZKE: It was indirect.

CHAIRMAN STETKAR: You want to purse the --

MEMBER BLEY: No.

CHAIRMAN STETKAR: I want to pick up, you need to help me a little bit. I really, and again, I echo Dennis's, this is kind of a really clever way of trying to get your hands around a difficult problem that you really don't have a lot of information about, despite all the numbers in this table.

What I was saying, and I understand exactly what you did with all the Boolean math and the combinatorics, and all that kind of stuff. It's kind of neat.

What bothers me though, and perhaps you might help me out is, I'll go back to my earlier questions about, what is a Common Cause Initiating Event versus a Single Unit Initiating Event? And how did you think about those sites that have very integrated shared systems?

I think that, my sense is that this works very, very well for sites, and you mentioned in the introduction, so I can echo that. Sites like Vogtle where the two units are, let's call them for practical purposes nominally identical. But they basically don't share anything except for maybe the switch yard.

I mentioned sites like, and I can mention, you know, I'll use Zion as a good example. Because it's not as politically charged as perhaps other sites. But Zion shared service water, component cooling water, instrument air, diesel generators, AC power, DC power. It was basically a single two unit site.

And it's not clear that this process works very well, unless the left hand column on this Slide 26, that internal event CDF, unless that column applied really, really carful success criteria for those shared systems for events that can effect both units, like loss of service water, like loss of offsite power, like loss of component coolant water, maybe loss of instant air, maybe fires in common areas, maybe floods in common areas.

We had a common auxiliary building between the two units. We had a common turbine building between the two units. So can you help me a little bit how you thought about that? Because there are a number of, I don't know how many. I'm familiar with some units on this list that do have very closely integrated shared systems.

MEMBER CORRADINI: Can I just ask? Because I know what John's asking. But I'm curious. If that's an issue, is there a way to get to a simplified estimate using your technique? Because I'm trying to understand. I understand what you did and how you tried to simplify it down.

But here I've got, instead of 1,085 megawatts, I've got 2,200 megawatts of stuff, all essentially with shared systems. So isn't that just one bigger plant?

MR. STUTZKE: Potentially. I guess it's a bigger plant. For example --

MEMBER CORRADINI: With a double PRA.

MR. STUTZKE: -- the big plant, the big Zion plant had five diesels. None of these plants have five diesels. So, for example, the single unit numbers for any of these are not a five diesel type number, you know.

MEMBER CORRADINI: Understood.

MR. STUTZKE: So a five diesel number is something smaller than probably many of these numbers. But something a lot larger than these numbers squared.

MEMBER BLEY: The good news is there aren't a lot of plants with that kind of design.

MR. STUTZKE: That's right.

MEMBER BLEY: There are a few on this list that have even more complex --

CHAIRMAN STETKAR: Oh, yes.

MEMBER BLEY: -- share in that, yes.

CHAIRMAN STETKAR: Sorry.

MR. STUTZKE: But I would, I guess there's a couple of things. One is our SPAR models are generally not definitive as to what unit they model. There are some notable occasions, differences. For example, Vogtle is a Unit 1 and Unit 2 model. And we will argue that that is the CDF for both units, like that.

There are unique SPAR models for I think plants like Browns Ferry. But not always. I think there's a 1 and 2 model, and then there's Unit 3, like that. So the level of resolution within the SPAR models is not probably fine enough to let you go after one unit. It's really asymmetrical from the other, like that.

But the other thing that I would argue is, if you flip back to Slide 23 here, look at what the equation results. The issue is, I have all these contributors to single unit risk. And I'm tasked with deciding, are they common cause or are they single units, all right?

And I've got to make a choice. It's one or the other in the equation. If I err on the fact that they're Single Unit Initiators, then that right hand term, that n squared term will drive the answer, like this.

On the other hand, if I have systems that are highly shared between them, where I think they're Common Cause Initiatives, it's driven towards the n term in the equation, like this.

CHAIRMAN STETKAR: But, Marty, that's not the way the math works. The Common Cause Initiators by definition are only seismic events and high winds. They are not losses of offsite power.

MR. STUTZKE: They are --

CHAIRMAN STETKAR: They are not the plain vanilla losses of offsite power that happen a lot more frequently than seismic events.

MR. STUTZKE: They are the initiator that caused both units to be challenged simultaneously.

CHAIRMAN STETKAR: They are not losses of offsite power.

MR. STUTZKE: Which are generally not losses of offsite power or LOOPs. So the LOOPs show up in the --

CHAIRMAN STETKAR: Single unit.

MR. STUTZKE: -- Single Unit Initiators.

CHAIRMAN STETKAR: And my whole, you know -- Let me give you an example. The single unit, pick Zion again. The single unit, Zion Unit 1 core damage frequency accounts for loss of offsite power initiating event. And it's an internal event, initiating event. It's not a seismic event.

And you need failures of, I'll pick a number, let's call it three diesels. And those diesels could have common cause failures, beta gamma. That gives me three diesels. It's not five diesel failures. Unit 2 doesn't have three diesels for that same loss of offsite power initiating event, it's only got two.

But if I get common cause failures of all five, I have no diesels for both units. This notional model doesn't account for things like that. It can't, because the notional, the combinatorics presume that the number for Unit 1 also applies to Unit 2, in terms of the conditional core damage probability, given the loss of offsite power initiating event.

CONSULTANT SHACK: But isn't some of that covered in his propagating and cascading probability?

CHAIRMAN STETKAR: No, because --

CONSULTANT SHACK: So if he comes back to --

CHAIRMAN STETKAR: No. He presumed that the cascading is small. And I'm saying that they're completely --

CONSULTANT SHACK: No. He didn't say it was small. He just said it was an inequality between the cascading and the propagating.

CHAIRMAN STETKAR: And he used that to justify discarding the other --

CONSULTANT SHACK: Right.

CHAIRMAN STETKAR: -- term in the equation.

CONSULTANT SHACK: So it isn't a question of small. It's a question of whether you believe that inequality on 22.

CHAIRMAN STETKAR: Well, and that's essentially what I'm -- I don't believe that inequality on 22 for sites that have very highly integrated shared systems. For selected sets of initiating events, like losses of offsite power, losses of cooling water, it challenged the shared.

Turbine trip, you know, fine. Reactor trip, you know, those kind of initiating events, yes, I'll buy that inequality for those. And I think it's, the only place that I kept hanging up are those sites that do have those very integrated shared support systems, AC power, DC power, cooling water, and so forth.

And some of Dennis's concerns I think also translate into shared spaces, you know, which also tend to be those, the plants that have shared support systems, you know.

CONSULTANT SHACK: Probably, yes.

CHAIRMAN STETKAR: It's like Zion. The, you know, common turbine building, common auxiliary building, where the conditional core damage probability of a flood in a particular area is not equal between the two units. But then, you know, I mean, that's one of the, you come up with whopping conservatism he's got with the tornado CDF.

CONSULTANT SHACK: Yes. But the tornado --

CHAIRMAN STETKAR: Almost overwhelms things.

CONSULTANT SHACK: Yes. But if you look at the map that is very conservative. But it doesn't effect much of anything at all.

CHAIRMAN STETKAR: It's sort of the major contributor to the total CDF in many cases.

MEMBER SCHULTZ: In fact it's the, almost anything.

CONSULTANT SHACK: Yes, there's a couple that it's not.

CHAIRMAN STETKAR: There's a couple that it's not. But, I mean, it really pushes things --

MEMBER CORRADINI: But I think, you'll find in the right hand column that in an awful lot of the cases the n squared single unit stuff is driving the number, when you look at the math.

CHAIRMAN STETKAR: Sure.

MEMBER CORRADINI: It's not a 90 percent 10 percent. It tends to be about two-thirds, one-third roughly. So even though the tornadoes are an important contributor, let's say to that one-third, they are not driving the right hand column.

The n squared single unit stuff tends to be the more important contributor. But there are exceptions. But it tends to be the more important contributor to the overall conclusion. And especially when you get up to, you know, the three unit sites, it's mostly the single unit stuff.

CHAIRMAN STETKAR: That's true.

MEMBER CORRADINI: Three unit sites again are?

MR. STUTZKE: Browns Ferry, Oconee and Palo Verde.

MEMBER CORRADINI: Palo Verde.

MR. STUTZKE: Browns Ferry is kind of a three unit site.

CHAIRMAN STETKAR: It's sort of a two and a one with some cross ties. I mean, in terms of the concerns that I was raising.

MR. STUTZKE: Right.

CHAIRMAN STETKAR: It's different.

MEMBER SCHULTZ: In the approach taken it turns out to be different.

CHAIRMAN STETKAR: Yes. I don't have, you know, unless you have some enlightenment over those? And I also don't know, I mean, I'm familiar, I know Browns Ferry. We've mentioned Browns Ferry. I know at least one other plant on this list that has at least pretty integrated shared electric power. And I'm not familiar with all of the plants. So I don't know if there are others.

I think the process does work really well for those sites that don't share systems. And quite honestly, I mean, you know, the reason I asked you about the SPAR success criteria is, if SPAR carefully accounted for that sharing.

In other words, in my Zion example, if SPAR only took credit for two and a half diesels, or something like that, or a 50 percent probability that Unit 1 had that shared diesel. If the SPAR models did that you'd be, I'd have a lot more confidence, you know.

MEMBER SCHULTZ: Yes, and the --

CHAIRMAN STETKAR: But if they took credit for, you know, the full sharing, and on some of the plants it's pretty extensive.

MR. STUTZKE: You know, the SPAR models are benchmarked against licensees' PRA models. Not just in terms of the numbers they produce. But, you know, our contractors at Idaho review to see that they're being produced. So, you know, in the case where systems are being heavily shared, you know, what you're suggesting is perhaps we've all missed the boat somehow.

CHAIRMAN STETKAR: Well, you know, the only reason I've raised this is I've seen, and this is not in the U.S. I have to, my experience over the last pretty much decade and a half has been overseas.

And I've seen many PRAs developed over there using the same standards that we use, that basically say, I'm doing a PRA for a single unit. And they'll take credit for sharing anything they can get their hands on.

MR. STUTZKE: Oh, yes.

CHAIRMAN STETKAR: Because well, just because they do that. And I don't know how people are doing that, you know, today, in either the site specific models that people have developed over the last nine years or so, or in SPAR models.

MEMBER BLEY: Now, I think a lot of the things John's raised, there might be some simple things you could do within the SPAR model to cover this, at least in a bounding way.

CHAIRMAN STETKAR: There might be. But you have to think about it pretty carefully. That's the whole notion, is you have to think about it.

MEMBER BLEY: But I don't know if there's a good list of which of the plants that --

CHAIRMAN STETKAR: I don't know. I mean, you know, I only know anecdotally a couple on this list.

MEMBER BLEY: Back in the old ACEP program they kind of laid out what the pieces of all the systems were in the plants that were around at that time.

MR. STUTZKE: And it might not be so bad to find, you know, it depends almost on the vintage of the FSAR.

CHAIRMAN STETKAR: Yes.

MR. STUTZKE: That's said of Vogtle.

There's like in Chapter 1 that says, here's everything we have that's shared.

CHAIRMAN STETKAR: Yes.

MEMBER BLEY: Right.

CHAIRMAN STETKAR: Yes.

MR. STUTZKE: So I'll have to find it.

CHAIRMAN STETKAR: I actually, quite honestly, last night I tried to look up a couple FSARs. And I found one that spelled it out pretty well. I found another that I knew had shared systems, where it was -- If I knew what I was looking for I could see how the words might describe what I was looking for.

MR. STUTZKE: Exactly.

CHAIRMAN STETKAR: But if I wasn't looking for it, the FSAR, it wasn't very clearly leading me in the direction that I needed to be led. I mean, obviously the site, this is not an infinite number of plants. So the site resident inspectors would certainly be cognizant of what the shared systems were.

MR. STUTZKE: Yes. Perhaps the regional SRAs could find it.

CHAIRMAN STETKAR: You'd hope at least, certainly the resident inspectors would know.

MEMBER BLEY: In any case, this does a nice job already of saying, you don't see any giant problems working there. That's very helpful. I don't know that our Level 3 project's going to narrow this issue. Because I think that plant's a nice one.

CHAIRMAN STETKAR: That's right. I mean, the Level 3 will give us some insight about the seismic, you know, site level, seismic flooding, those types of things, high winds.

MR. STUTZKE: Right.

CHAIRMAN STETKAR: And it will give us some insight about multi-unit releases translating out into Level 3 risk. Your, you know, your nominal ten to the minus three scaling factor for the latent cancer risk. But it won't help the left hand side of this.

MEMBER BLEY: It will help those other issues, I suspect. You'll look at timing of releases and that sort of thing.

MR. STUTZKE: Yes. You'll get insights and operator actions in times like this. Because one, for example, at Vogtle one of the issues that you have here is how does the second unit actually get tripped? It's easy enough if there's some sort of shared system. And at Vogtle that wants to be the switch yard. So I can worry about that.

But other, under what other circumstances would the second unit actually get challenged? And what

I'm going with in that case is the site emergency response guidelines, which are the high level procedures. This is for the emergency director to come in and decide when he needs to notify state and local authorities, et cetera.

And there's a line item in there that says, think about what you want to do if the other unit. Maybe you should think about shutting it down. Or maybe it's not the right time to shut it down. So the assumption, you know, that I'm likely to make in the Site Level 3 is, well, upon core damage in one unit, the other unit is going to be shut down, just because I have to reach some decision.

Again, I'll point back at Chernobyl. Units 1 and 2 continued to operate for a day after Unit 4 had already destroyed itself. And then they got the order, okay, shut it down. Rather remarkable.

MEMBER BLEY: Well, I'd also go back to your, you don't have to go to it, Slide 20, your Venn diagram. The way you've broken this out with the cascading sequences and the propagating sequences. I think many people would have not even though to chasing the propagating sequences without this structure. I think that's --

MR. STUTZKE: I was worried that would be the driver. Because the frequency of the propagating sequence is much higher than the core damage coming up. And, in fact, one of the things I debated is, aren't those already included in the other initiating event frequencies when I count them?

And I've gone through at least a fair amount of the initiator. You can't find examples of multi-unit trips very often. They just don't happen very often. I guess my favorite one was an incident a while back at Braidwood. You'll love this one.

Where, I can't remember which unit tripped. But they had normal turbine trip. And they had a misaligned valve. And they filled up, I think it was the condensate tank or their feed tank. And the water overflowed and spilled on the switch gear, and tripped the second unit.

CHAIRMAN STETKAR: That's a good one.

MR. STUTZKE: Classic. It's like, oh, I never would have thought to model that. So yes, we have looked. Actually, you may be familiar with the IBM Watson, the contacts come for analytics to find things. We had looked through by, manually all of the multi-unit LERs that we could find.

And our approach was very crude, to say look, find me two LERs for the incident of date, which was only 24 hours from each other. And then we'll come down and look and see, like this.

Well, we intend to use this software from Watson to see what it can find. And see, well, are there multi-unit implications for some of the sites. Can't find it now. Save us from reading the LERs.

MEMBER BLEY: How many of those near time trips did you find?

MR. STUTZKE: It was only about 50 or so.

MEMBER BLEY: That's more than I --

MR. STUTZKE: I mean, and --

CHAIRMAN STETKAR: Since day one? Yes, I wouldn't, that's not surprising.

MR. STUTZKE: You know, and a majority of them are LOOP related, you know, like the great northeast blackout a couple of years back, you know, ten years ago or so, you can find multiple trips then.

CHAIRMAN STETKAR: That just --

MR. STUTZKE: You know, I haven't found any where both units went down for like a, you know, a service water, or a CCW. I was looking for that. Or, you know, one unit went down, and we got excited and shut the other unit down as a precaution, or something like that. And I haven't found any of those either.

MEMBER SCHULTZ: You know, the insights

you're talking about now are very interesting to explore, given what you've done here analytically. You talked at first about the internal peer review, and checking and evaluation of the model, and the concept. And you mentioned also you're taking it to PSAM. Have there been external reviews, peer reviews at this point?

MR. STUTZKE: No. The only other people that have seen this work -- Well, I mean, it is publicly available. There's nothing hidden. And, you know, the math is belabored because the old Generic Issues process said, document everything so it's independently reproducible. And I think we've fallen kind of short like that.

In January I attended a meeting of the CANDU Owners Group. And they're very interested in what they call whole site risk. They're in the process of re-licensing some plants.

And their regulators got, you know, said, you need to worry about site risk for times like that. And I have informally shared this with members of the CANDU Owners Group.

MEMBER SCHULTZ: Good.

MEMBER RAY: Look at shared heat sink event. I know there have been power reductions.

CHAIRMAN STETKAR: Power reductions are

pretty common. Especially close to the site.

MEMBER RAY: And if they get close to trips --

MR. STUTZKE: Salem, in particular. Salem's had a couple. I'm not sure if they actually tripped. But they essentially weren't making any power.

MEMBER RAY: I've had to dive in plants to do a unit plan.

MR. STUTZKE: It's the analogy, when you do common cause data. And you're looking for examples where two pumps failed, or three valves failed. And the preponderance of the evidence is, something failed. And the other one wasn't feeling so good, okay. It's hard to find clear cut cases where two things failed like we actually model.

MEMBER RAY: Well --

MR. STUTZKE: So, you know, these power reductions, or things like that -- But I, you know, you've --

MEMBER RAY: Seaweed ingress, for example. Happens to both units at the same time typically, when there's an off shore storm.

MR. STUTZKE: Right. But yes, we will continue to hunt down the LERs to see. You know, I'd like to find some real examples of the sorts of scenarios that we're modeling here. Or at least precursors to them to get a feel for what's real. Very good.

CHAIRMAN STETKAR: Excuse me. Didn't get my coffee in. My voice is going away. Any members have any more questions for the staff?

MEMBER BALLINGER: I have a sort of naive question. If you were to relax the assumptions, or do it a sort of more rigorous way in your mind, what's your judgment? How much would that change?

MR. STUTZKE: Well, I have pursued it at a sequence level for the Common Cause Initiatives, where every sequence is individually accounted for, not smeared together. And you get the same result. And it's not required then that the plants be identical. But it is required that the consequences can be added together.

MEMBER BALLINGER: Yes, got it.

MR. STUTZKE: And you will get the same result. But it's not the case in the Single Unit Initiators.

MEMBER BALLINGER: Right.

MR. STUTZKE: You get terms like, you know, the frequency of something happening. And, you know, one times the consequence in Unit 2. It's like, boy, those terms are hard to deal with.

MEMBER BALLINGER: What do you mean by hard to deal with? Hard to deal with from a technical point of view? Or hard to deal with because they're big?

MR. STUTZKE: Hard to deal with in the sense I can't say I bounded it --

MEMBER BALLINGER: Oh.

MR. STUTZKE: -- and delete them. You know, they remain in the equation. And you can't show that one is bigger than the other.

MEMBER BALLINGER: Is there a reason to continue because you're uncertain that there might be a big effect?

MR. STUTZKE: Well, I think the real way, it's what I said before. I probably chased this bit of arithmetic as hard as I can chase it for right now, for this notional model.

What I'm hoping is that when we get done with Site Level 3 project, I'll be able to smoke test this against the actual results we get from the PRA, and see how one comes. The problem is, because Vogtle doesn't share many systems, I'm not going to get at the real issue.

CHAIRMAN STETKAR: That's the only problem. Had it been at a different site you would have been able to really check off all of those boxes.

MR. STUTZKE: In which case I'll raise my hand and say, please let us do, you know, a different site where we can try to explore these sorts of things.

MEMBER BLEY: Well, one thing you might, from this work and from that, and all of the thinking about this you're doing, it may be reasonable to put together some guidance on doing full site risk assessment. What you need to do to your PRAs to extend it to cover this issue.

MR. STUTZKE: Well, in addition to this work I'm doing with the CANDU Owners Group, IAEA is sponsoring a meeting on multi-unit risk. And it will be in Ottawa in November of this year. And IAEA is a sponsor, CSNC is a sponsor, and NRC is a sponsor.

And we're trying to collect, you know, thoughts like this. I know Carl will be up there again, and Bob. Because they have some strong thoughts on how to do this.

You know, quite frankly, what I've learned on the international front was, people are now becoming appreciative of a problem that nobody's really thought about in any great detail. I mean, why can't I just multiply it by n? You know, scale it up.

MEMBER SCHULTZ: Recalling early papers

associated with SMR evaluations, and I believe it was an end time approach, multiplied by n.

MEMBER BLEY: That was mostly done. There's been some stuff in the past looking at the timing issues, and seeing what that does to the source terms.

MEMBER SCHULTZ: Yes, right.

MR. STUTZKE: You know, and I know you guys and Carl traced Seabrook pretty heavily, like that. But again, it's not as shared a system.

MEMBER BLEY: Right. Seabrook again was a lot closer again to Vogtle.

MR. STUTZKE: It's relatively isolated. And so you don't know where you get it.

MEMBER CORRADINI: So if we were to pick from the current population of plants something that John was worried about, about shared, what would be some candidates?

(Simultaneous speaking.)

MR. STUTZKE: Well, Browns Ferry comes to mind.

MEMBER BLEY: But it's so unique that it's hardly worthwhile.

CHAIRMAN STETKAR: Farley, if I can share. Farley has some bizarre electric power sharing. They had sort of a single --

MR. STUTZKE: Right.

CHAIRMAN STETKAR: My recollection was, there's sort of one dedicated diesel for each unit. And there are three others that are kind of shared. And they're sort of a two unit, two train per unit plant. I don't remember the cooling water systems there.

MR. STUTZKE: Turkey Point used to have a, what I called a one and half ECCS.

CHAIRMAN STETKAR: Yes.

MR. STUTZKE: A partner CCS that would decide where it needed to put you, needed help.

CHAIRMAN STETKAR: Anything more for the staff? I have a couple of administrative things to do here. And then we'll go around the table. First of all, do we have any comments from anyone in the audience? I think we have the --

MEMBER SCHULTZ: John, I did have one question for John. You talked about things changing. And I wanted to get an appreciation for the schedule for changes that. Is there one laid out for --

MR. KAUFFMAN: Yes.

MEMBER SCHULTZ: -- modification of that?

MR. KAUFFMAN: There's a schedule laid out. I don't happen to have it with me. The MD is out for comment now. And it is to be finalized by November of this year.

MEMBER SCHULTZ: Good. Thank you.

CHAIRMAN STETKAR: Thanks. I'm sorry, Stephen. I didn't mean to cut you off. We do have the bridge line open. I know we had some folks on the bridge line.

Just for our help, if there's someone out there could you just say something, so I can confirm that it's open? We, unfortunately don't have any other more efficient way to do that. So if someone's out there, could you please just say something?

MR. STALLONE: Yes. I'm Marty Stallone.

CHAIRMAN STETKAR: Oh, wait. Thank you. Thank you very much. I really appreciate that. Now, if there's anyone out there who has any comments that they'd like to make, we'll entertain those. Hearing none, we'll re-close the bridge line.

And as usual for subcommittee meetings, I'd like to go around the table and see if any of the members have any final comments that they'd like to make. And I'll start off with our esteemed consultant first.

CONSULTANT SHACK: Well, I was very interested in it. I thought it was an interesting thing. The discussion today helped me understand the difference between Ps and Qs a little better. And seems largely the heart of the matter. One minor question. Does that go back to the '47 paper? Is that where you dig that out of?

MR. STUTZKE: Yes.

CONSULTANT SHACK: Okay. I'll go chase that a little bit more.

MR. STUTZKE: That's just plotting points.

CONSULTANT SHACK: Yes, I know. I plot points a lot.

MR. STUTZKE: I like it because I can remember it. It's what I was taught at University of Maryland. I think if the choice of plotting point changes your answer you're probably up to no good.

CONSULTANT SHACK: I'm all set.

CHAIRMAN STETKAR: Harold?

MEMBER RAY: Well, I guess I would just say, or observe, that LERs, licensees don't like to submit LERs. And they only do it when they have to. And I think if we limit our exploration of events to those which forced an LER to be submitted, it would be too narrow a population of data.

And, I'd just say, come close to a number of events that are relevant to all of this, both on the switch yard side and the cooling water side, and so on. They didn't trigger LERs.

But, believe me, they should be taken note of in this kind of work. It's looking at low probability event. And I don't know how to do that, other than through some expert panel, or something of that kind. And that's all I want to say.

CHAIRMAN STETKAR: Great. Steve?

MEMBER SCHULTZ: I really appreciate both presentations that we heard this morning, and the work that's gone into both the process improvement, as well as you John. And then for Marty, the analytical work here. Clearly a lot of both thoughtful approaches, as well as the detailed analytics.

I'm very interested to learn about the response from peers at PSAM, as well as in November as the SMR conference, risk conference. It's very important. And I'd certainly like to hear more about this in about a year, associated with the response.

And I'm glad you're using what you've gotten from the calculational structure to then look at what the operational experience can also tell. Thank you.

CHAIRMAN STETKAR: Dennis?

MEMBER BLEY: Yes, I literally, I think it was a nice covered job. But I think the more broad thing I'm interested in is I think we ought to explore this process of looking at this stage on these the way we do with the reg guys.

I mean, they come in, we parse them out to one person to look and see if the committee ought to look at it. And I think that would be helpful. We ought to be thinking about these issues as they arise. And I think that would be helpful for us.

CHAIRMAN STETKAR: When you say as they arise, probably when they get to this stage? That's discreet, yes.

MEMBER BLEY: That's arise for me.

CHAIRMAN STETKAR: Okay. I didn't want to leave the impression of when they first --

MEMBER BLEY: No, no.

CHAIRMAN STETKAR: -- something first comes across their desk. Mike?

MEMBER RYAN: Nothing else, John. Thank you. Thank you for your presentation.

CHAIRMAN STETKAR: Joy?

MEMBER REMPE: I wanted also to express my thanks. But I also agree with Steve that I hope that there is some follow-up after your meetings, the IAEA meeting. And I think after we look at the SMRs that are coming through that it would be relevant. So hopefully there is some follow-up.

CHAIRMAN STETKAR: Mike?

MEMBER CORRADINI: I guess I have a question for Marty. So, you're doing this after the memo came out in December, as just an interested individual that can't get your hands off of it? Or has RES been given the user need to pursue this?

MR. STUTZKE: To pursue?

MEMBER CORRADINI: This further.

MR. STUTZKE: This further? No. This is --

MEMBER CORRADINI: It's a done deal?

MR. STUTZKE: It's done.

MEMBER CORRADINI: So, the reason I'm asking a question like that is, to me this is going to come up again, and again, and again. So it seems to me whether there's a user need or not, this would be useful to do. So, let me just ask the question.

Is the staff asking something from us that we could help move that along? Or is the staff happy that this is not a user need, and it's dead, and I'm the only one?

CHAIRMAN STETKAR: Mike, for some perspective you're not aware of, the staff didn't come to us, we asked them to come.

MEMBER CORRADINI: Ah.

CHAIRMAN STETKAR: So Marty's not pursuing this in the interest of his being really interested in following stuff. We asked him to --

MEMBER CORRADINI: Because you're home at night, and you have nothing better to do.

CHAIRMAN STETKAR: I'm sure Marty lives, breathes and eats this stuff.

MEMBER CORRADINI: What I'm really asking is, this may seem as a non user need at this point within the staff. But I have a funny feeling this is going to come back very quickly.

CHAIRMAN STETKAR: Right.

MR. STUTZKE: Well, you know, there's a couple of things. One is, we as a staff are generally interested in this multi-unit sort of thing. So, I mean, within the Office of Research, because of the Site Level 3 project, NRO had its working group for the multi-module risk paper, like that. We've gotten funding to go on big international trips, like to Toronto and Ottawa.

(Simultaneous speaking.)

(Laughter.)

MR. STUTZKE: For the record, I stayed at the Toronto Airport hotels.

CHAIRMAN STETKAR: It was December, no doubt.

(Simultaneous speaking.)

MR. STUTZKE: But we generally had this intent to continue to pursue it. Like I said, IAEA has talked to us, and we'll go play it with them.

MEMBER CORRADINI: Okay. Thank you. Then I have nothing.

CHAIRMAN STETKAR: As a final comment I don't have anything else to add, other than thanks a lot for bringing all of this together, and taking the time to educate us on the process. I think it is a really clever analysis.

And as one final closing comment, if you want to hear about somebody who had a simultaneous dual unit trip of 2,040 megawatts going off line like that, come and talk to me. And with that, we are adjourned.

(Whereupon, the meeting in the above-entitled matter adjourned at 10:35 a.m.)

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Advisory Committee on Reactor Safeguards (ACRS) Sub Committee Generic Issues Program Overview

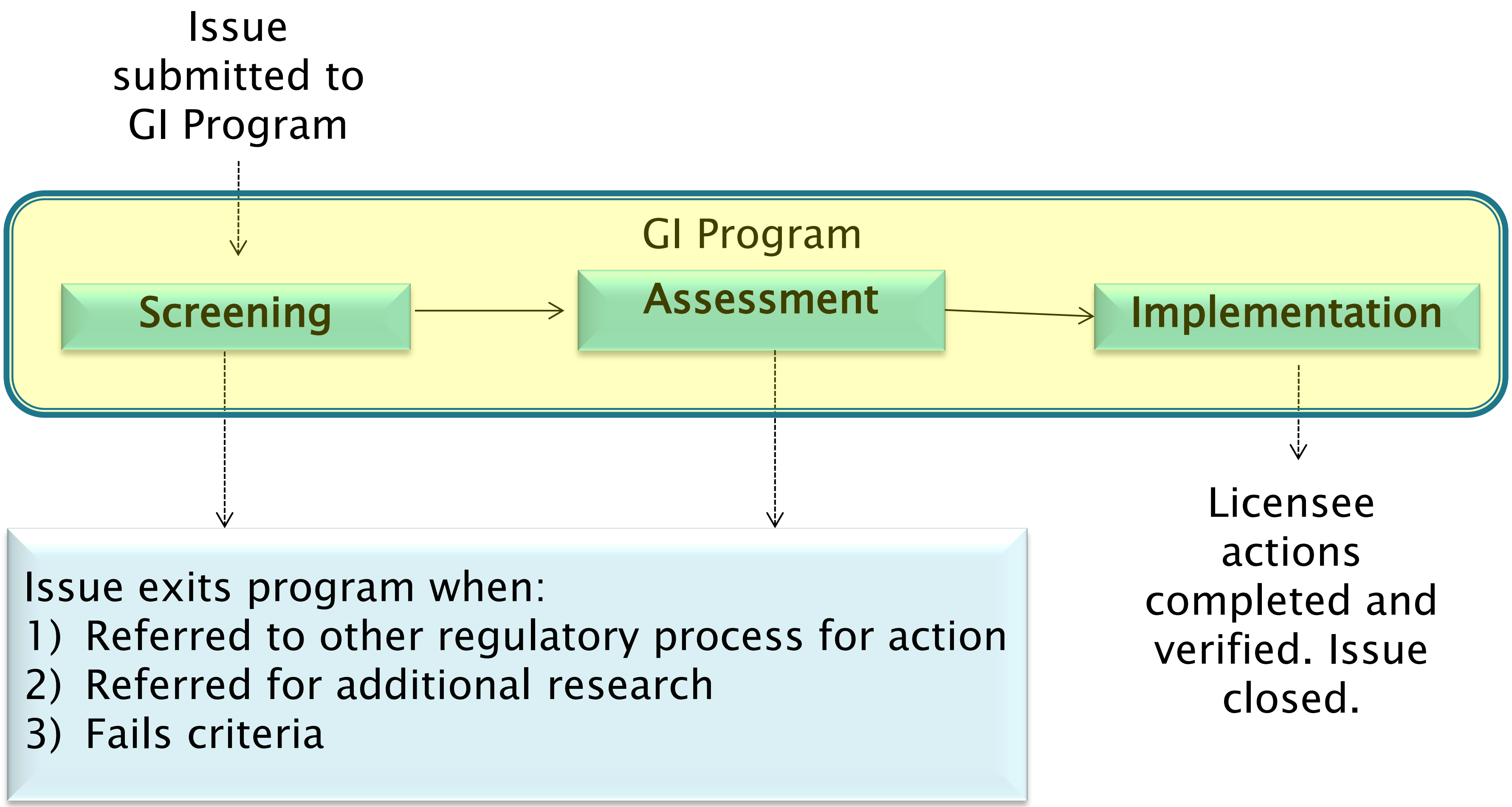
Regulatory Guidance & Generic Issues Branch
Office of Research

March 5, 2014

Background

- Staff initiated screening process for Generic Issues (GI) program
- Multi-unit risk issue became a pre-GI in 2008
- Memo with results issued 12/2/2013 (screened out on low risk and ability to adequately determine risk)

3 Stage GI Program



GI Criteria

1) Must affect public health and safety
2) Applies to two or more facilities
3) Is not readily addressable through other established regulatory processes
4) Can be resolved by regulation, policy, or guidance
5) Can have its risk or safety significance adequately determined or estimated
6) Must be well defined, discrete, and technical
7) Must involve review, analysis, or action by the licensees

Multi-unit events

- Multi-unit core damage sequences may:
  - challenge the ability of the plant operating personnel
  - require resources beyond those available for single units
  - increase offsite consequences
- Current siting of units
  - 32 sites with 2 operating reactors
  - 3 sites with 3 operating reactors
  - Some sites are physically near each other
- Quantification of risk requires development of a PRA that addresses above issues

GI Process Results

- GI Criterion:
  - Must affect public health and safety, which includes a risk significance component
- A highly simplified (notional) analysis suggests that multi-unit risk for sites with currently operating plants are likely to meet the NRC safety goal policy for single units
- Interim regulatory actions are not necessary while pursuing further insights into multi-source site risk

GI Process Results

- GI Criterion
  - Risk or safety significance can be adequately determined (i.e., does not require longer term studies to evaluate).

- Multi-source site risk is extremely difficult to analyze for all unique site characteristics and plant designs, as confirmed by ongoing RES research for one site

Going Forward

- NTTF follow-up actions are further reducing multiunit risk for low probability/high consequence events.
  - On-site and off-site equipment
  - Procedures
  - Emergency response staffing
  - Seismic and flooding walkdowns

- Staff is continuing to pursue further insights into multi-source site risk as part of ongoing efforts, e.g. Level 3 PRA
  - NRC staff is developing Level 3 PRA for one multi-unit site
  - Results anticipated on 2017

Notional Model for Multi-Unit Risk

Martin Stutzke, RES/DRA

Agenda

- Background
- Delineating multiunit accident sequences
- Mathematical derivation
- Example estimates

Remember that all models are wrong;
the practical question is how wrong do they have to be to not be useful.

Box, G. E. P., and Draper, N. R., (1987), *Empirical Model Building and Response Surfaces*, John Wiley & Sons, New York, NY

Multiunit Site Statistics

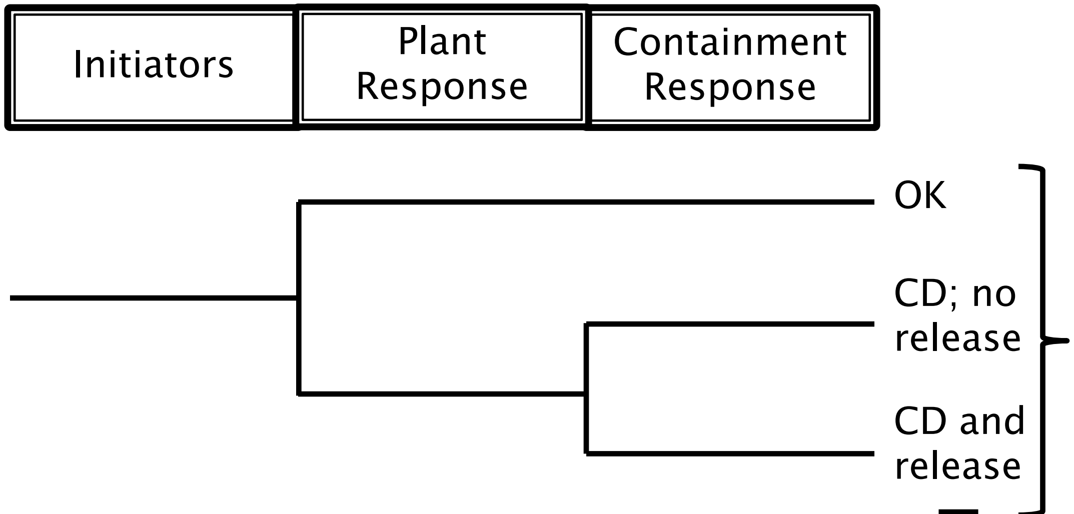
Category	Number of Sites	Notes		
Dual-unit sites	30	ANO Beaver Valley Braidwood Brunswick Byron Calvert Cliffs Catawba Comanche Peak D.C. Cook Diablo Canyon	Dresden Farley Hatch Indian Point La Salle Limerick McGuire Millstone North Anna Peach Bottom	Point Beach Prairie Island Quad Cities St. Lucie Sequoyah South Texas Surry Susquehanna Turkey Point Vogtle
Triple-unit sites	3	Browns Ferry Oconee Palo Verde		
Adjacent sites	2	Salem 1&2 and Hope Creek Nine Mile Point 1&2 and FitzPatrick		

These counts exclude the two-unit San Onofre site where both units are being permanently shutdown, the two additional units under construction at the Summer site, and the two additional units under construction at the Vogtle site.

Site Risk Assessment

- Site risk = risk to the public due to operation of the nuclear power plants at a site
  - Accidents that affect one radiological source (typical PRA)
    and
  - Accidents that affect combinations of radiological sources
- Sources of radiological hazard
  - Reactors
  - Spent fuel pool
  - Dry cask storage
- Approaches
  - Site Level 3 PRA
  - Naïve estimate (number of units x single-unit risk)
  - Notional model (adapt the results of a single-unit PRA to estimate the total site risk)

Simple View of a Level 3 PRA



Any sequence may cause an initiator in one or more other units

Need to consider the dependencies among units

<u>Set of Release Sequences</u>

- Frequency, Λ_i
- Consequence ,C_i

$$risk = \sum_{i=1}^{n} \Lambda_i C_i$$

<u>Practical Limitation</u>
May only have high-level risk and frequency contributors (not the individual sequence frequencies and consequences)

Classes of Initiating Events

- Common-cause initiators (CCIs): Simultaneously challenge all units at the site (e.g., earthquakes)
- Single-unit initiators (SUIs): Challenge one unit, but may cause multiunit accidents due to:
  - Shared support systems
  - Spatial interactions (e.g., flood and fire propagation pathways)
  - Common-cause failures
  - Operator actions
- The distinction between CCIs and SUIs is a key concept for developing the notional model!

Nomenclature and Assumptions for CCI Risk Contribution

n = number of identical units

f_{CCI} = frequency of the CCI

$p_{k,CCI}^{(n)}$ = Pr{release from exactly k of n units | CCI}

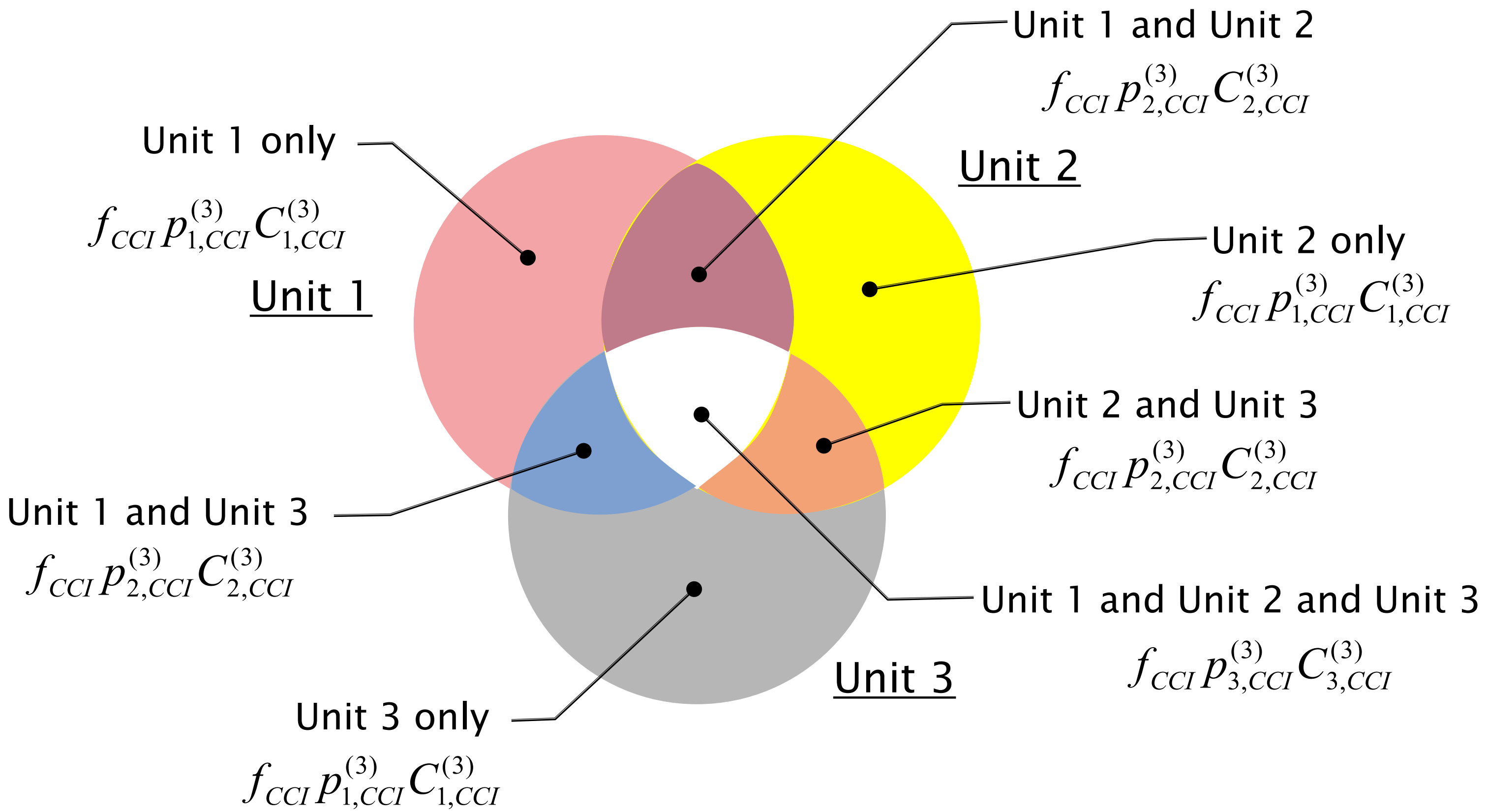
$C_{k,CCI}^{(n)}$ = frequency weighted average consequence due to release from exactly k of n units after CCI

<u>Assumption #1</u>: The units are identical

<u>Assumption #2:</u> Consequence is proportional to the number of units involved

$$C_{k,CCI}^{(n)} = k\, C_{1,CCI}^{(n)}$$

CCI Contributions to Multi-Unit Risk



Risk Due to CCIs

Expression for single-unit risk due to CCIs (add the parts within one circle)

$$R^{(n)}_{\text{single-unit},CCI} = f_{CCI} C^{(n)}_{1,CCI} = f_{CCI} \sum_{k=1}^{n} \binom{n-1}{k-1} p^{(n)}_{k,CCI}\, C^{(n)}_{1,CCI}$$

Expression for multiunit risk due to CCIs (add all of the parts)

$$R^{(n)}_{S,CCI} = f_{CCI} \sum_{k=1}^{n} \binom{n}{k} p^{(n)}_{k,CCI}\, C^{(n)}_{k,CCI}$$

After using Assumption #2 and simplifying:

$$R^{(n)}_{S,CCI} = n\, f_{CCI}\, C^{(n)}_{1,CCI} \sum_{k=1}^{n} \binom{n-1}{k-1} p^{(n)}_{k,CCI} = nR^{(n)}_{\text{single-unit,CCI}}$$

SUI Sequence Taxonomy

- Cascading sequence: Core damage and release in the unit where the SUI occurred, and also in one or more additional units
- Propagating sequence: No core damage or release from the unit where the SUI occurred, but core damage and release in one or more additional units
- Restricted sequence: Core damage and release only in the unit where the SUI occurred

Nomenclature for SUI Risk Contribution

n = number of identical units

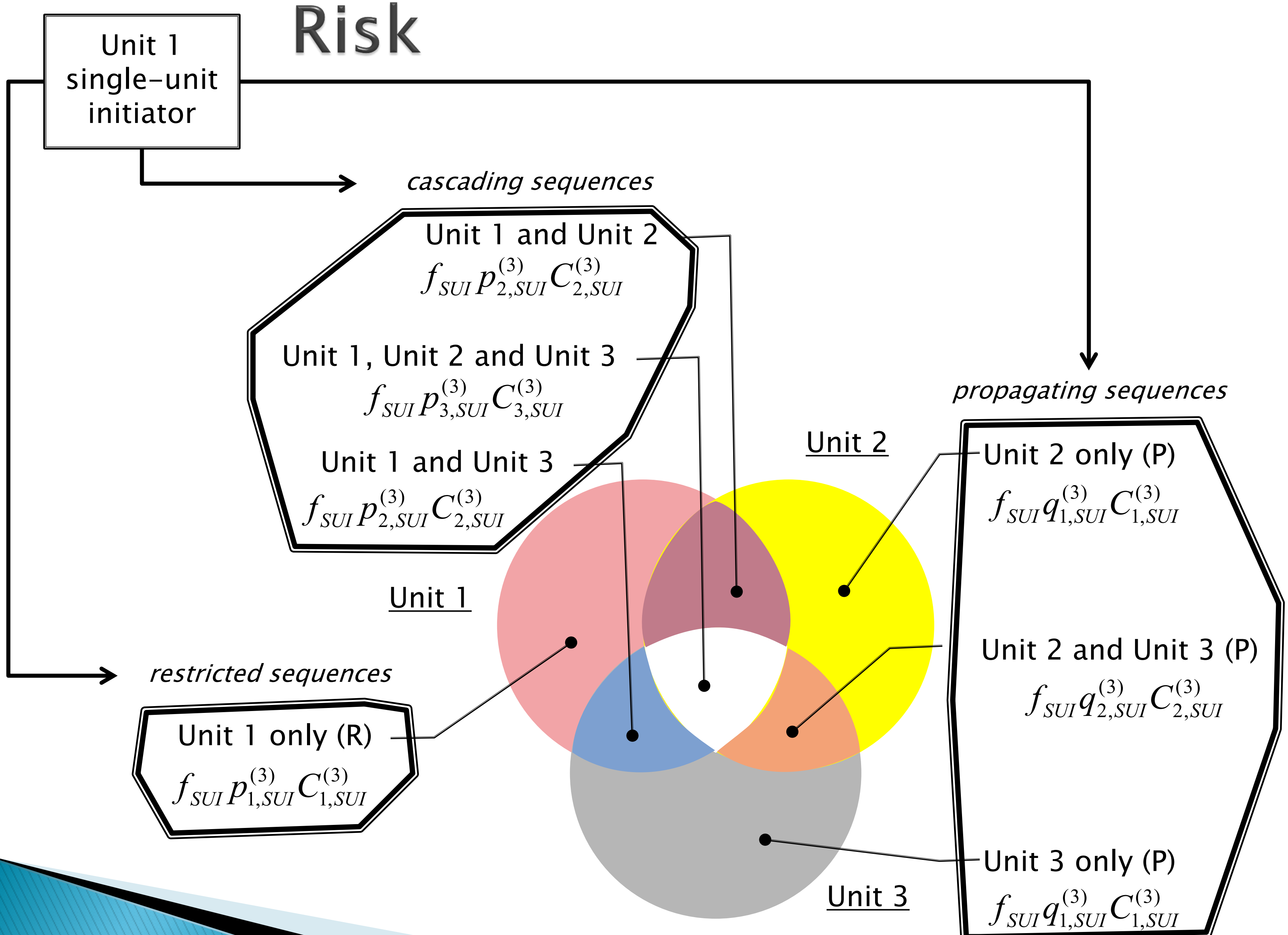
f_{CCI} = frequency of the SUI

$p_{k,CCI}^{(n)}$ = Pr{release from exactly k of n units due to restricted and cascading sequences| SUI}

$q_{k,CCI}^{(n)}$ = Pr{release from exactly k of n units due to propagating sequences | SUI}

$C_{k,CCI}^{(n)}$ = frequency weighted average consequence due to release from exactly k of n units after CCI

CCI Contributions to Multi-Unit Risk



Risk Due to SUIs

Using Assumption #1, the expression for multiunit risk due to SUIs is:

$$R_{S,SUI}^{(n)} = nf_{SUI}\left[\underbrace{\sum_{k=1}^{n}\binom{n-1}{k-1} p_{k,SUI}^{(n)}\, C_{k,SUI}^{(n)}}_{\substack{\text{restricted and}\\ \text{cascading}\\ \text{contribution}}} + \underbrace{\sum_{k=1}^{n-1}\binom{n-1}{k} q_{k,SUI}^{(n)} C_{k,SUI}^{(n)}}_{\substack{\text{propagating}\\ \text{contribution}}}\right]$$

Risk Due to SUIs (Con't.)

Using Assumption #2 and simplifying:

$$R_{S,SUI}^{(n)} = n^2 \underbrace{f_{SUI} C_{1,SUI}^{(n)} \sum_{k=1}^{n} k \binom{n-1}{k-1} p_{k,SUI}^{(n)}}_{\text{single-unit risk due to SUIs}} - n(n-1) f_{SUI}\, C_{1,SUI}^{(n)} \sum_{k=2}^{n} \binom{n-2}{k-2} \underbrace{(p_{k-1,SUI}^{(n)} - q_{k-1,SUI}^{(n)})}$$

The q's include the probability that the SUI causes an initiator in one or more additional units as well as the probability of core damage and release in one or more additional units. So:

$$p_{k-1,SUI}^{(n)} > q_{k-1,SUI}^{(n)}$$

As a result:

$$R_{S,SUI}^{(n)} < n^2 R_{\text{single-unit},SUI}$$

Total Multi-Unit Site Risk

$$R_S^{(n)} < n\, R_{\text{single-unit},CCI} + n^2\, R_{\text{single-unit},SUI}$$

- Can bound the total multiunit site risk using the results of a single-unit PRA
  - Only need to partition results into CCI and SUI contributions
- Method provides little insight into risk contributors
- Needs further development to include:
  - Shutdown and low-power states
  - Spent fuel (spent fuel pool and dry cask storage)

What Does It All Mean?

- There is no guidance for acceptable site risk
  - During formulation of the Safety Goal Policy Statement in the early 1980s, the Commission decided not to impose a bias against multi-unit sites (*Safety Goals for Nuclear Power Plant Operation*, NUREG-0880, Rev. 1, May 1983, ADAMS Accession No. ML071770230, page 33, 2nd paragraph)
  - SRM dated 9/14/2005 to SECY-05-0130, *Policy Issues Related to New Plant Licensing and Status of the Technology-Neutral Framework for New Plant Licensing*
  - Quantitative health objectives (QHOs) currently interpreted on a per-reactor basis, e.g., the derivation of risk surrogates in App. D of NUREG-1860, *Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing*
    - QHO for individual early fatality risk $\leq$ 5E-7/y $\leftrightarrow$ LERF $\leq$ 1E-5/y
    - QHO for individual latent cancer fatality risk $\leq$ 2E-6/y $\leftrightarrow$ CDF $\leq$ 1E-4/y
- One way to proceed: Compare the site risk to the per-reactor QHOs. If site risk < single-unit QHOs, then no immediate safety concern

Example Application: Estimate of Site Individual Latent Cancer Fatality Risk

- Frequency information:
  - SPAR and SPAR-EE models (80% flood multipliers)
  - NFPA 805 submittals (80% fire multipliers)
  - Earthquakes (GI-199)
  - Tornados (NUREG/CR-4461)
- Consequence information:
  - NUREG-1150
  - SOARCA
  - Scoping multiunit MACCS2 calculations, which indicate than multiunit risk is less than linear (sub-additive)
  - Conditional probability of latent cancer fatality (CPLCF) ranges from 10^{-5} to 10^{-3}; used 10^{-3}

Scoping Estimates of Multiunit Site ILCFR

Site	Units	Single-Unit Initiators								Common-Cause Initiators				Site
		Int. Events	Internal Flood			Internal Fire			Total	Seismic		Tornado	Total	
		CDF	Source	Multiplier	CDF	Source	Multiplier	CDF	CDF	Source	CDF	CDF	CDF	ILCFR
Arkansas Nuclear	2	7.2E-06		0.55	4.0E-06		5.7	4.1E-05	5.2E-05	GI-199	4.1E-06	7.2E-05	7.6E-05	3.6E-07
Beaver Valley	2	5.6E-05		0.55	3.1E-05		5.7	3.2E-04	4.1E-04	GI-199	4.8E-05	7.1E-06	5.5E-05	1.7E-06
Braidwood	2	8.7E-06		0.55	4.8E-06		5.7	4.9E-05	6.3E-05	GI-199	7.3E-06	4.1E-05	4.8E-05	3.5E-07
Browns Ferry	3	4.1E-06		0.55	2.2E-06		5.7	2.3E-05	2.9E-05	GI-199	5.4E-06	1.1E-04	1.2E-04	6.2E-07
Brunswick	2	8.7E-06		0.55	4.8E-06	NFPA 805		1.5E-05	2.9E-05	GI-199	1.5E-05	1.8E-05	3.3E-05	1.8E-07
Byron	2	1.3E-05		0.55	6.9E-06		5.7	7.1E-05	9.1E-05	GI-199	5.8E-06	4.1E-05	4.7E-05	4.6E-07
Calvert Cliffs	2	2.1E-05		0.55	1.1E-05		5.7	1.2E-04	1.5E-04	GI-199	1.2E-05	8.9E-06	2.1E-05	6.5E-07
Catawba	2	3.0E-05		0.55	1.6E-05		5.7	1.7E-04	2.1E-04	GI-199	3.7E-05	2.1E-05	5.8E-05	9.7E-07
Comanche Peak	2	1.5E-05		0.55	8.4E-06		5.7	8.7E-05	1.1E-04	GI-199	4.0E-06	2.0E-05	2.4E-05	4.9E-07
D.C. Cook	2	3.3E-05		0.55	1.8E-05	NFPA 805		1.3E-05	6.5E-05	GI-199	1.2E-05	8.8E-05	1.0E-04	4.6E-07
Diablo Canyon	2	1.6E-05		0.55	8.7E-06		5.7	9.1E-05	1.2E-04	licensee	4.0E-05	1.2E-07	4.0E-05	5.4E-07
Dresden	2	8.5E-07		0.55	4.7E-07		5.7	4.8E-06	6.2E-06	GI-199	1.9E-05	4.1E-05	6.0E-05	1.4E-07
Farley	2	2.3E-05		0.55	1.3E-05	NFPA 805		5.9E-05	9.5E-05	GI-199	2.8E-05	3.2E-05	6.0E-05	5.0E-07
FitzPatrick/Nine Mile Point														2.2E-07
FitzPatrick	1	4.3E-06		0.55	2.3E-06		5.7	2.4E-05	3.1E-05	GI-199	6.1E-06	1.0E-05	1.6E-05	
Nine Mile Point	2	1.2E-05		0.55	6.3E-06	NFPA 805		2.1E-05	3.9E-05	GI-199	5.6E-06	1.0E-05	1.6E-05	
Hatch	2	7.2E-06		0.55	4.0E-06		5.7	4.1E-05	5.2E-05	GI-199	2.2E-06	2.2E-05	2.4E-05	2.6E-07
Hope Creek/Salem														6.5E-07
Hope Creek	1	5.3E-06		0.55	2.9E-06		5.7	3.0E-05	3.9E-05	GI-199	2.8E-06	8.4E-06	1.1E-05	
Salem	2	3.4E-05	SPAR-EE		8.3E-05	SPAR-EE		2.8E-05	1.5E-04	GI-199	7.4E-06	8.4E-06	1.6E-05	
Indian Point	2	9.7E-06	SPAR-EE		3.1E-06	SPAR-EE		5.4E-05	6.7E-05	GI-199	1.0E-04	8.4E-06	1.1E-04	4.8E-07
La Salle	2	3.2E-06		0.55	1.8E-06		5.7	1.8E-05	2.3E-05	GI-199	3.7E-06	4.1E-05	4.5E-05	1.8E-07
Limerick	2	2.3E-06	SPAR-EE		4.1E-08	SPAR-EE		4.2E-06	6.4E-06	GI-199	5.3E-05	8.4E-06	6.1E-05	1.5E-07
McGuire	2	7.4E-06		0.55	4.0E-06		5.7	4.2E-05	5.3E-05	GI-199	3.1E-05	2.1E-05	5.2E-05	3.2E-07
Millstone	2	4.1E-06		0.55	2.2E-06		5.7	2.3E-05	3.0E-05	GI-199	1.5E-05	8.4E-06	2.3E-05	1.7E-07
North Anna	2	1.3E-05		0.55	7.0E-06		5.7	7.3E-05	9.3E-05	GI-199	4.4E-05	8.9E-06	5.3E-05	4.8E-07
Oconee	3	1.4E-05		0.55	7.9E-06	NFPA 805		6.1E-05	8.3E-05	GI-199	4.3E-05	2.5E-05	6.8E-05	9.6E-07
Palo Verde	3	8.9E-06		0.55	4.9E-06		5.7	5.1E-05	6.4E-05	see note	3.8E-05	1.3E-07	3.8E-05	6.9E-07
Peach Bottom	2	3.4E-06	SPAR-EE		5.3E-08	SPAR-EE		6.6E-07	4.1E-06	GI-199	2.4E-05	6.6E-06	3.1E-05	7.8E-08
Point Beach	2	9.3E-06		0.55	5.1E-06		5.7	5.3E-05	6.8E-05	GI-199	1.1E-05	2.7E-05	3.8E-05	3.5E-07
Prairie Island	2	4.1E-06		0.55	2.3E-06	NFPA 805		5.2E-05	5.8E-05	GI-199	3.0E-06	5.3E-05	5.6E-05	3.5E-07
Quad Cities	2	4.3E-06		0.55	2.4E-06		5.7	2.5E-05	3.1E-05	GI-199	2.7E-05	1.3E-04	1.6E-04	4.4E-07
Saint Lucie	2	2.7E-06		0.55	1.5E-06		5.7	1.5E-05	1.9E-05	GI-199	4.6E-05	7.8E-06	5.4E-05	1.8E-07
Sequoyah	2	1.4E-05		0.55	7.7E-06		5.7	8.0E-05	1.0E-04	GI-199	5.1E-05	4.1E-05	9.2E-05	5.9E-07
South Texas	2	8.4E-06		0.55	4.6E-06		5.7	4.8E-05	6.1E-05	GI-199	6.3E-06	5.3E-06	1.2E-05	2.7E-07
Surry	2	2.8E-06	SPAR-EE		5.0E-05	SPAR-EE		5.3E-06	5.9E-05	GI-199	5.7E-06	8.9E-06	1.5E-05	2.6E-07
Susquehanna	2	1.9E-06		0.55	1.0E-06		5.7	1.1E-05	1.4E-05	GI-199	1.3E-05	1.3E-05	2.6E-05	1.1E-07
Turkey Point	2	1.7E-06	SPAR-EE		1.0E-08	NFPA 805		7.3E-05	7.5E-05	GI-199	1.0E-05	4.6E-06	1.5E-05	3.3E-07
Vogtle	2	3.1E-05		0.55	1.7E-05		5.7	1.8E-04	2.2E-04	GI-199	7.1E-06	1.4E-05	2.1E-05	9.4E-07
													maximum	**1.7E-06**

Palo Verde seismic CDF estimated shortly after the Fukushim Dai-ichi event using GI-199 methods

Less than the per-unit QHO