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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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STRUCTURAL ANALYSIS SUBCOMMITTEE

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WEDNESDAY

OCTOBER 3, 2018

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 1:00 p.m., Peter Riccardella, Chairman, presiding.

COMMITTEE MEMBERS:

PETER RICCARDELLA, Chairman

MICHAEL L. CORRADINI, Member

RONALD G. BALLINGER, Member

MARGARET SZE-TAI Y. CHU, Member

VESNA B. DIMITRIJEVIC, Member

JOSE MARCH-LEUBA, Member

HAROLD B. RAY , Member

JOY L. REMPE, Member

GORDON R. SKILLMAN, Member

MATTHEW SUNSERI, Member

DESIGNATED FEDERAL OFFICIAL:

GIRIJA SHUKLA

ALSO PRESENT:

JOSE PIRES, RES

MEHDI REISI-FAHRD, NRR

C-O-N-T-E-N-T-S

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

(12:58 p.m.)

CHAIRMAN RICCARDELLA: The meeting will now come to order. This is a meeting of the ACRS Structural Analysis Subcommittee. I am Pete Riccardella, Chairman of the Subcommittee. ACRS members in attendance are, Vesna B. Dimitrijevic, Margaret Sze, Harold Ray, Gordon Skillman, Mike Corradini, Matt Sunseri, Joy Rempe, Jose March-Leuba, and Ron Ballinger. We may or may not have two other members come in later.

Girija Shukla of the ACRS is the Designated Government Official for this meeting.

The ACRS reviews and advises the Commission in regard to licensing and operation of production and utilization facilities and related safety issues, the adequacy of proposed reactor safety standards, technical, and policy issues related to the licensing of evolutionary and passive plant designs, and other matters referred to it by the Commission.

The purpose of this Subcommittee meeting is for the staff to brief Subcommittee on the topic of Correlation or Dependency of Seismic Performance of Similar SSCs. This is the topic of a research publication, NUREG/CR-7237, Correlation of Seismic

Performance of Similar SSCs.

Members of the -- this is also the topic of a research review, and I want to note that this briefing that we're having here is independent of the research quality review. That quality review is well under way and the panel, the research panel is here but they've pretty much already completed their review.

The Subcommittee will gather information, analyze relevant issues and facts. And formulate proposed positions and actions as appropriate. The meeting will be open to the public. We have not received any written comments, or any requests for time to make oral statements from members of the public regarding today's meeting.

A transcript of the 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.

Participants should first identify themselves, and speak with sufficient clarity and volume so that they can be readily heard. To avoid interruption of the meeting, please mute your individual lines during the presentations and committee discussions. Also please silence your phones. And I just, I've been advised that --

MEMBER CORRADINI: Yes, just for everybody. So this test of the Emergency Broadcast System via mobile is going to happen in a little bit more than an hour. My recommendation is that you power off your phones --

CHAIRMAN RICCARDELLA: Before.

MEMBER CORRADINI: -- before 2 o'clock so it, because it will broadcast whether you have your phone muted or not.

MEMBER MARCH-LEUBA: Yes, but alternatively, you can put it in airplane mode.

MEMBER CORRADINI: It'll still --

MEMBER MARCH-LEUBA: Airplane mode --

MEMBER CORRADINI: Won't do it. It'll still broadcast through it.

MEMBER MARCH-LEUBA: Airplane mode?

MEMBER CORRADINI: Yes if you power -- you're going to have to poser it off.

MEMBER MARCH-LEUBA: Let's try a test.

MEMBER CORRADINI: Okay, go ahead.

(Laughter.)

MEMBER CORRADINI: Feel free.

CHAIRMAN RICCARDELLA: Let me, just for those members who weren't on the Research Review Committee, just a little bit of an introduction in my simple way of looking at it, at the topic.

Suppose you have three pieces of equipment, pumps that are required -- that are in parallel, and one of them is required to work in an accident sequence. And let's assume that the probability of failure of each of those pieces of equipment at a given level earthquake is 0.1. Okay.

If the components are independent then the probability of none of them working is .1 of q, or 10 to the minus 3. On the other hand if they are dependent, if the three are dependent, the probability that if one fails, they're all going to fail, so the probability is .1. And that's the significance that we're talking about.

And current seismic PRA's there's a rule of thumb which I'm sure Jose and others will discuss that in some cases you assume they are perfectly correlated, which is the 0.1. And in other situations you assume that they're totally uncorrelated, which is the 10 to the minus 3.

And I think what came to my mind when I reviewed this was the potential significance with respect to NuScale, where you might have 10 or 12 reactors in a common site. And you have a big earthquake, you know, is the probability -- you know, you could get into a 10 to the minus ten, 10 to the minus 12th situation versus a .1 probability that they'll all fail.

So, that's why I thought it might be a good idea to have this meeting. And I think this meeting will also serve as sort of some education for the members of the committee who weren't on the quality review.

MEMBER SKILLMAN: Pete, let me ask this, for the record, I'm Dick Skillman. In this argument, or in this example that you just explained, the way I interpret that is if these three components are identical, are operable, that means they're not pulled along. They are in trigger, ready to go. And at the same location, thus experiencing the same physical behavior --

CHAIRMAN RICCARDELLA: Yes.

MEMBER SKILLMAN: Then all that you've just mentioned is accurate. But of the three pumps, if one is a 14 stage, one's a 13 stage, one's a 12 stage, one is in total lock, and one is on a different set of supports. Then there is basis for the licensing to claim, not identical, different response, and here's the response data for, you know, the shaker table test I did for these. Therefore, the seismic dependency while interesting, doesn't take out all of my components. Is that an accurate framework for this?

CHAIRMAN RICCARDELLA: Yes, and there's current rules of thumb for how you handle that, okay.

MEMBER SKILLMAN: Okay, thank you.

CHAIRMAN RICCARDELLA: But as I understand it, in fact even for those three identical pumps there are aspects of their seismic fragility which are correlated, and aspects that aren't correlated. Okay, and so the reality is probably somewhere between zero and one.

And for example, you know, if I think a seismic qualification test is probably a lot like a fatigue test. I run ten identical fatigue tests on the same pieces of equipment, and the equipment can, you know the samples will fail sometimes anywhere between 1000 and 10,000 cycles, or 100,000 cycles. And so there's a -- that's a total randomness that even for identical equipment exists.

So, but this report is aimed at something in between those extremes of zero and 1. And with that I'll let Jose and the Research staff proceed.

MR. PIRES: Good afternoon, I am Jose Pires. I am a Senior Technical Advisor in the Division of Engineering, in the Office of Research. I'm really the main preparer of this briefing because this project was conducted by the Division of Engineering. We had the lead for this project.

In the preparation of these slides, and in preparation for this meeting, I discussed with some other colleagues. I discussed with Selim, various topics related to the issues of correlations. He's a Seismic PRA Analyst. So he has experience in that area. So if I could benefit from it. He's sitting here if his help is needed to answer some questions that I may not be able to answer.

And Mehdi, he works at NRR and he's been involved in the reviews of Seismic PRAs that have been submitted as part of the 2.1 Evaluation. So he can provide some perspectives also. I also discussed with him issues of seismic dependency, seismic failure dependencies. And he can provide some perspectives of what is being done nowadays in this area to address this issue.

CHAIRMAN RICCARDELLA: Yes, perhaps some perspective on the significance of it. In other words if you did have a more accurate way of treating it, would it have a significant effect of some PRAs or not?

MR. PIRES: And I just in case that if we talk about the applicability of some of these methodologies here to these modular reactors, I also talked to someone at NRO that is more familiar with what is going on in relation to new reactors. So he's sitting here too, and if necessary can also help answer some things, if necessary, he can.

So, this is pretty much the outline. And so I will try to focus mainly on the research before us. And on the research that was then. So I'll talk some about the objectives, some background leading to research objectives and goals, how we thought these could be used. The scope of the work.

And I quickly go, we're talking about the approach and everything. I think it's probably a good thing to talk about some aspects of the analysis. So I'll, the treatment of correlations he's used in the seismic PRA analysis. And what his methodology, what are the enhancement that these methodology provide?

So this analyses aspect can go back to the approach, it was a methodical approach involved in the review of the existing PRAs to see what is the significance of the correlations on the analyses, or the dependencies.

Review of current literature, and various methodologies that I used. The project also involved workshops with experts. And those workshops were useful. Those are mostly seismic fragility knowledge experts. They provided insights.

We questioned them for instance about what is their data? Are they experimental data or experienced data that somehow could be useful in a more data driven approach? And we'll talk about that later.

Then we'll talk about what will be the process of implementing this methodology in the seismic PRAs? It's really an obvious process but then what could be issues associated with that, the use of this methodology? Then I will summarize.

Right now, I say so that we have to, I guess your introduction already covered that, that the Seismic PRA risk, Seismic Probability Risk Assessments have been done worldwide. And not just in the United States for quite a long time too, more than three decades. And some key aspects there, I guess one of the aspects is that one has to consider all possible earthquake levels in the PRA. And so the frequency of occurrence of what we would say, some earthquake size is what we relate to in the seismic hazard.

And then do a proper convolution of the fragilities expressed in terms of those earthquake size with the hazard, seismic hazard. That has been addressed.

Topic today is that the earthquakes can simultaneously damage multiple, redundant components for example. And then also for similar components, all at the same time. So, and that there is quantification should account for that.

I have some pictures here just to try to illustrate --

MEMBER RAY: Excuse me, I wanted to ask a question on the slide before. The phrase, "all possible earthquake levels". What does that mean?

MR. PIRES: Well, that means that the seismic hazard should encompass the true scope of the hazard. You know, not artificially have a limitation. Is what the results of the probabilistic seismic hazard analysis produce that should all be accounted for in the seismic probability statistics.

MEMBER RAY: So there's no limit on the range of probability, or is there a cutoff?

MR. PIRES: No, in principle there should not be any, I mean. But what happens in practice is that after some levels the probabilities are so small that they can be neglected.

MEMBER RAY: Sure.

MR. PIRES: But they theoretically are possible.

CHAIRMAN RICCARDELLA: Okay. You know, you have a probability of occurrence of an earthquake of various sizes and as the earthquake gets larger obviously that probability goes down. But, you know, they'll consider ground motions from .1g up to greater than 1g. You know, 1g, 2g and they'll consider them incrementally. And then each one of those earthquakes has an uncertainty distribution around it as well. Each one of those --

MEMBER RAY: Yes, I understand Pete, I was just wondering if they at some point as he said, the probability is low enough that it's cut off?

MR. PIRES: Yes, I --

MEMBER RAY: And I didn't know what all possible --

MR. PIRES: That's what is meant. And in many ways it's probably -- I don't like it. In the case of the earthquake hazard, you somehow have to choose now that it can come, go over the entire range, and both of these very low probabilities. So, you can do that.

CHAIRMAN RICCARDELLA: But, I think, also when you say all possible earthquake levels, they're really referring to the peak ground acceleration, which is, you know, the ZPA, the g level of that. They're not considering all multiple possible spectra for a given GPA, are they?

MR. PIRES: Yes, the hazard will give us that. For a site, it can give us the ground motion response factor. And so, it dramatically could vary, but normally in the bins of interest, it does not vary much for a particular site. But if necessary, that could be accounted for and make the process more complex.

(Off microphone comment.)

CHAIRMAN RICCARDELLA: Okay.

MR. PIRES: So, I went and got some pictures of earthquakes of first design -- looking at power plant components. This is just to show that sometimes really, we have structures or components that are side-by-side for the same earthquake, and some fail, and others do not fail, for a variety of reasons.

And like the Northridge earthquake in

1994, north of Los Angeles, near the San Fernando Valley. You can see there, some buildings, I think, yes, the ones on the right, the first floor collapsed. It's very typical on some of these old constructions. First floor is soft, collapses.

The buildings now have one less story and there are people living on that story or occupying those facilities. Normally they are garages, so there will be loss of life.

The performance faction for those buildings typically is no collapse and no loss of life. And the ones on the left, they do have structural damage, but they did not collapse. They are like very close to each other. I'm not saying these are just purely statistical considerations, there may be other factors. But this is an example.

Below is an apartment building, it was a similar situation. You can see the ones on the left, in the front have two story. The other on the left is three story. And the first story also collapsed. They are near, they're right next it, they did not.

I find interesting the components, the electric power components, designed in a substation. This was in Haiti, and you can see those components. One would expect they all fail, because they typically are not very robust for seismic loads. In this particular case, only one failed. The others were on. That does not mean that the substation did not fail because there is a power flow going there, it's a different issue.

This is in a power plant, but is not a nuclear power plant in Guam, in an earthquake, and its motor control centers. We don't know if they all failed. But if they all failed they had different failure modes because obviously one had a tilt-out failure mode. The others might have had other functional failure mode. I don't know, but at least the failure modes were different in these phase.

Now, actually with the experience data, I caution, sometimes it is very difficult to interpret, because we don't have all information. But in this case one would expect that the ground motion would be similarly, the basic citation would be similar upon all of them.

I just put one more here, these are tanks. They are many makeup water tanks at the facility they had built in place. And they normally tend to all fail in an earthquake, but however the failure modes are different for many of them. So there is a possibility not all fail.

In this case, they all had damage. There is buckling off the shelf, there are some anchor supports. So there may have been, they have different failure modes. The one on the bottom right, sliding which I don't understand. So there are issues in each case. Sometimes not so obvious.

CHAIRMAN RICCARDELLA: The bottom left is anchorage for the tank?

MR. PIRES: It's, I think it's an anchor system that there was a lift off there.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: Some amount of liftoff. I cannot know, may not know the details of those, but these was presented at one of the workshops, and was a few years ago. But it illustrates that in some cases you have multiple failures. Almost all the components or structures fail. In other cases we really don't have, in our observations of those.

MEMBER REMPE: Has any effort been made to recently, to try and understand those differences? Differences in anchorages, or there's just not data to try and --

MR. PIRES: Oh, no. There --

MEMBER REMPE: -- understand this?

MR. PIRES: There are a lot of studies.

With tank facilities there are quite a few studies.

MEMBER REMPE: Say it again. Could you be closer to the mic? I'm having trouble hearing you.

MR. PIRES: With tank facilities there are several studies to understand those behaviors. They may not be looking at the same thing as we do in terms of correlations. But, you know, there are a lot of different, natural gas storage tanks, gas, and other things like that. So these are critical facilities. There is a good understanding of their behavior.

MEMBER REMPE: But I mean at Daini, do they know why there were different failure --

MR. PIRES: Oh, at Daini?

MEMBER REMPE: -- modes as you've indicated here?

MR. PIRES: I think this is to be expected that there will be multiple failures of the water, of these water tanks. Now, I have not done an analysis of those. And I have not seen a report on those.

MEMBER REMPE: It just seems like, that an important piece of information is to try and understand what data are there, and can you extract some insights from that data? And so examples, not only over in Japan, but in the U.S. If we could try and understand the differences it would be an important aspect to investigate.

MR. PIRES: That was parts of the workshops on these projects.

MEMBER REMPE: Right.

MR. PIRES: The workshops for these projects had experts that typically go to every earthquake that has major damage. They normally go there as part of their professional work. They were gathered to the workshop and they provided input. So, and there is some conclusions that came out of that work.

MEMBER REMPE: And when I reviewed those conclusions, the data --

MR. PIRES: Well that, the data is very difficult to interpret and back calculate.

MEMBER REMPE: And that's why I'm asking this question. It seems like where there are data, one should try to understand it before trying to model it. And it's --

MR. PIRES: Yes, it's fraught with uncertainties. And to the extent, Fukushima people who developed models, tried to correlate them with what exists in practice. But we cannot trust the data by itself directly. You have to have the modeling, and the knowledge, and the testing.

(Simultaneous speaking.)

CHAIRMAN RICCARDELLA: You're probably talking --

MR. PIRES: From the aspect HPS.

CHAIRMAN RICCARDELLA: You're probably talking a big research project just to model one situation like this. Model all the tanks and, you know, you're probably, it's probably a research project in itself that's of equal cost of this NUREG.

MEMBER REMPE: In other fields once you get the model that's based on the data, you turn around and find another place, and see if you can apply that model, and if it can be validated. And so that's why I'm more interested in the data before I get interested in the model.

MR. PIRES: It is done. The experts working on the field of tanks for example, they try to always see how their results correlate with data. But there are uncertainties on that.

MEMBER REMPE: Yes.

MR. PIRES: What happens in the field normally does not have all the information that you would like for a full benchmark.

MEMBER REMPE: Yes, I understand.

CHAIRMAN RICCARDELLA: Jose.

MEMBER MARCH-LEUBA: I find interesting a couple slides before, it's very visual. One more, there. The picture on the right is really, that one. You had to tell me what happens on the floors, the missing floors. But when I look at that one I clearly see one failed, three that didn't.

MR. PIRES: Yes.

MEMBER MARCH-LEUBA: Will these be relevant only for only, quote-unquote, marginal earthquakes? So it was, and by marginal I mean an earthquake that is close to the acceleration where you fail?

CHAIRMAN RICCARDELLA: Are you talking about the Haiti?

MEMBER MARCH-LEUBA: The Haiti one.

CHAIRMAN RICCARDELLA: Okay.

MEMBER MARCH-LEUBA: I mean this one, it tells me one failed, three didn't.

CHAIRMAN RICCARDELLA: Yes.

MEMBER MARCH-LEUBA: On the houses you have to tell me what happened. Although it's clearly worse.

MR. PIRES: Yes.

MEMBER MARCH-LEUBA: But it is only for a small range of Gs that this will happen? If the acceleration had been ten percent higher, all of them would have failed? The acceleration would have been ten percent lower, none of them would have failed?

MR. PIRES: It's quite possible, it's quite possible. There in this, for this particular components they have prove --

MEMBER MARCH-LEUBA: No, but the basis of their method. Is that we're going to separate this plus-minus? Is this plus-minus ten percent? Is this plus-minus 50 percent with random variability versus --

CHAIRMAN RICCARDELLA: I would say, I'd be surprised if ten percent made --

(Laughter.)

CHAIRMAN RICCARDELLA: -- made that much of a difference.

MR. PIRES: I have no idea.

MEMBER MARCH-LEUBA: Yes.

MR. PIRES: In this particular, the ceramic components on the substation tend to be vulnerable. And so if the earthquake was stronger at site, you almost would expect all of them to fail. However, in this case, those cables going upwards do provide some support.

MEMBER MARCH-LEUBA: Oh, they're holding

it.

MR. PIRES: And that might have worked differently for the different components and that made the difference in this case. So it also however, those components, those cables going up, also may pull up the bus that goes overhead. So, you have to consider both cases.

MEMBER MARCH-LEUBA: Yes, this goes back to our conclusions. And I know Vesna is going to talk about that. This is going to be almost impossible to recommend. Because you need to know how tight are those cables on top?

MR. PIRES: Right. I meant, caution is that as far as nuclear power plants are concerned, this is not a component that appears in the PRA. But it's just an example. It's normally other components appear in nuclear.

This crisis in this case is an issue of what are the anchors on these cabinets?

CHAIRMAN RICCARDELLA: Go.

MEMBER SKILLMAN: Jose, on this image, on the lower left.

MEMBER MARCH-LEUBA: Here?

MEMBER SKILLMAN: No, the bolt. Very commonly, the construction for that bolt is a J-bolt that's been grouted or that's a Hilti that has pulled loose. But in either case, I interpret that to be a four or five inch displacement of the base of that tank against what had been the original forked bolt. That bolt has been pulled loose.

MR. PIRES: Yes, probably the bolt might have --

MEMBER SKILLMAN: The force that pulled the bolt loose was the ear on the tag that moved upward. It pulled the bolt right out of the ground.

MR. PIRES: Yes.

MEMBER SKILLMAN: Is that what you see in that image?

MR. PIRES: I would say that that is probably the correct interpretation. I would say, because I think there might have been an overturning moment, and the entire force on that bolt might have failed the bolt. And then it was sliding after that. But you could also fail the tank involved, depending on what is the weak link there? So it is, so either can be a weak link. Normally, it would probably, the bolt failure would be the --

MEMBER SKILLMAN: Likely, the bolt anchorage.

CHAIRMAN RICCARDELLA: The anchorage of

the bolt, anchor fail.

MR. PIRES: Not, the tank link itself would be the buckling. And that does not necessarily mean that there is a leakage of the water. But it is normally assumed that there is. But that does not mean that there is. It might still hold water.

There, so I'll just say that normally these, of course all these SPRAs normally involve a set of, a rule-based approach so to speak, on how to deal with the dependent failures. And typically data, two parameters that are important is the similarity of the components at the very high level and the proximity of the components.

So based on those two parameters now you have four cases, four combinations, similar components close by, similar components far apart. But a different storage, and dissimilar components close by, and far apart.

So the rule-bases account for those cases. And they try to make, I just put there two cases, and not in case I need to go here with all the details of the rule-bases. But obviously they are intent to be close together. They are close together, they are similar normally. And that's the baseline knowledge is assumed correlation on those failures.

MEMBER MARCH-LEUBA: So this is the state of the err. This is what everybody has been doing for the last 35 years.

MR. PIRES: That's what people do, yes. But is not the state of the -- I would say it is the state of the practice.

MEMBER MARCH-LEUBA: Right. People know better, but they're, right.

MR. PIRES: Right.

MEMBER MARCH-LEUBA: Now would you explain the logic? And I don't know anything about seismic responsive buildings, but I would expect that if a tank fails on the basement of a building, on floor five, they will fail too. And according to this, you failed them, you have correlation only if you're on the same floor, but not on higher floors?

MR. PIRES: Yes, that is a complicated situation. Because if you do a, calculate the structural response of a building, the acceleration is on the floors of the building. So that will be like the new ground for the components mounted there.

You can actually calculate the correlation factor between those, the accelerations on the various floors. And you can see that they, the correlation factor actually goes down. Can become small, around

.2 or .3. You know, if they are on the same floor it will be higher. But if there are different floors, you can start decreasing the correlation factor. It is not by necessarily, it could be 1 or even .5.

MEMBER MARCH-LEUBA: My point, just not knowing how this thing is done is, I would have done if one fails, all the ones that are in weaker positions, fail too.

MR. PIRES: If the ground motion that is higher than the one with the weakest ground motion fails, then that probably can happen. But there is, the correlation coefficient between the motion of the various floors does decrease with the --

MEMBER MARCH-LEUBA: So they --

MR. PIRES: -- floor level and the distance.

MEMBER MARCH-LEUBA: -- kind of the G forces are smaller on the 5th floor than on --

MR. PIRES: Well they normally are higher on the fifth floor. Because there is amplification to the top. But what I'm saying is the correlation coefficient between them.

MEMBER MARCH-LEUBA: What I would do if something fails on the 5th floor, doesn't mean the four, three, two, and one are bad. But if something fails on one, then two, three, four, and five are bad.

MR. PIRES: It depends on -- I see particularly there is an amplification as you go up. There is also a bandwidth on the ground motion. As you go up and amplify, you also have more narrower band ground motion. So, depending on what are the frequencies of the components, and IRS, and then we test those narrow bands and motions. So that also is another effect.

CHAIRMAN RICCARDELLA: Tends to go toward the natural frequency of the building.

MR. PIRES: Yes.

CHAIRMAN RICCARDELLA: And or the mode --

MR. PIRES: But in the lower floors the bandwidth is a lot broader.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: Tends to be broader.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: So, and, but that is captured. The response part, yes now is can capture it reasonably well. Is the capacity part in my opinion that is more difficult, for which it is more difficult to establish the correlations.

CHAIRMAN RICCARDELLA: So in a seismic puree, does the fragility, the person developing the fragility curves, he considers the difference in response say to a .5 g earthquake, between the 1st floor and the fifth floor? That's built into his fragility --

MR. PIRES: Yes.

CHAIRMAN RICCARDELLA: -- curves. So that's taken into account? So it's, the correlation is different than the magnitude of the response.

MEMBER MARCH-LEUBA: I have been told by some experts in this room that that was not the case. But obviously I was wrong.

MR. PIRES: How it is, it is.

MEMBER MARCH-LEUBA: I was misinformed.

MR. PIRES: You try to express all the fragilities in terms of the ground motion at one reference location. But the calculation of that accounts for the transfer function between these locations.

So the capacity of the component may be the same but the fragility can change because of the location, and the ground motion varies. So there is a difference there.

MEMBER MARCH-LEUBA: Yes, and I can see how the building can because of the natural frequency, can filter some. I mean you could have a high frequency, you have less shock upstairs than downstairs.

MR. PIRES: Yes, there is some of that. And, you know, the question is how much of that, of the process is involved some type of broaden of --

MEMBER MARCH-LEUBA: Yes.

MR. PIRES: -- of the motion. And so we are careful to do that. But those effects do exist.

MEMBER MARCH-LEUBA: It's a complex phenomenon.

(Off microphone comment.)

MR. PIRES: Those effects exist. The fact that the ground motion frequency content can change somewhat with the location, and is important.

So I guess one part of the background was that of course the methodology makes this bounding -- simplifying assumptions. Later on when we talk about the literature review, she'll review our mission that initially there was a set of simply finding assumptions that was more complex than these. But even that set of simply applying assumptions has fallen off somehow.

One of, of course sensitivity analysis are always done. I see the analysts pick up a baseline case and they do sensitivity analysis to see how important those aspects are.

Sometimes people expressed their idea that although these bands are large, you may mask some insights that otherwise would not be masked. If you had data more detailed than all this.

And now I would like to mention that the treatment, well I'm not saying that the treatment of dependencies the way it done now is deficient, or somehow inappropriate. The treatment of dependencies depend on the intended use of the results. And what is the need for those results?

So that is one aspect, and so that I would like to caution that the other thing is that the methodology that was developed that here, that might, will need further demonstrations and development.

But its use in those further demonstrations will definitely, are going to depend on our rising uses or needs.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: To my understanding the current uses and needs, what has been used, seems to be sufficient. But that may change.

CHAIRMAN RICCARDELLA: Okay.

MR. PIRES: So, I think particular applications, that some more elaborate studies have been that.

CHAIRMAN RICCARDELLA: You know, I think going back to the previous slide, I think it's, to me an important point is that insights that you might get. You know, for example if you have three pieces of equipment, maybe it would be smart to just change the mounting a little bit.

Make it, you know, come out and rotate them or put different size gaskets in there, or something. Just anything to make them not identical. You might reduce the -- you know, if it turned out to be significant it could have a significant --

MEMBER MARCH-LEUBA: But only for those pieces or components of the SPRA, defined as critical.

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: And which would be one or two, it won't be the whole plant.

CHAIRMAN RICCARDELLA: Yes, I would think the sensitivity analysis, you'd say well, I'll do it one way with everything 100 percent correlated. I'll do it a second time with everything percent zero correlated. And if the core damage frequency comes out the same, obviously doesn't matter, right.

MR. PIRES: In this, one of the slides later on says, of the implementation, all the use of these, what will be the process for use these? And of course the process is iterative. It starts with simply finding assumptions based on that, you identify those few, you know, cut-sets or accident sequences that need to be further refined and investigated.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: And you'll proceed that way.

MR. REISI-FARD: Can I provide a comment on that question?

MR. PIRES: Sure.

MR. REISI-FARD: So this is Mehdi Reisi-Fard. I'm an acting team lead in the Office of Nuclear Reactor Regulation. On the point that you had with respect to sensitivity analysis, in fact that's what the licensees do in some risk-informed applications like 50.69.

As a part of the NEI guidance to do those 50.69 evaluations, when they use seismic PRA, it is recommended to do, to assume full correlation and no correlation on the same floor, to just get their -- sites.

So that's part of the guidance that the industry is using currently for some of those applications.

CHAIRMAN RICCARDELLA: Yes, thank you.

MR. PIRES: Yes, I'd like to put this first bullet, you may think of it as a disclaimer, but I don't want to claim that what the current practice is necessarily not a good practice, you know. This, so I will go back what was the objective of the study. You know, the 2010, 2014 seismic constructional research plan in the Office of Research, initiated this study.

And those are the objectives of the study. So a lot of these topics, and if feasible to propose some refinements to the methodology that could provide those additional refinements, or could be more precise for needs that at that time were thought that might come up.

And at that time there were some studies going on, severe accident studies going on, that motivated part of this study, even though they were not PRA studies. The Level 3 PRA project was going to start. There was talk of modular reactors coming for, even though that far back there was already talk of that. And then that subsided somewhat, and then along it came it back again.

So, the Office was being prepared to address these issues. And this, the goals of course are that somehow the review that the report did, the opinions of the experts on the components that typically appear as critical, and that appear on the, as important in terms of dependencies, and other information there, could support staff reviews or peer reviews, you know. It's tool that could be consulted and used in those reviews.

And so, the methodology depending on the needs of potential applicants, and our staff in terms of their reviews could provide more insightful approaches.

Now the scope of the work as defined in the statement of work, it said, first part was, assess the impact of correlation and some different assumptions on the results of seismic PRAs that have been done to date, and that they read about. This concentrated on core damage frequency. They reviewed --

And so then, the other part was what we talked before. The review of what, an identification of an analysis method that could be an improvement, or thought it is now, but will not necessarily be a very cumbersome method. That will not involve a level of effort and work that would be another of magnitude higher. But maybe 50 percent more level of effort. So, and that was the intent there.

The third way, the third is of course identify a pathway so that this methodology could become standard. That of course is a more, does not depend on the NRC. Depends on the need of the industry.

MEMBER SKILLMAN: Jose, before you move that slide, for the first two bullets, how many examples, or how many calculations, or how many -- what is the population of the review, as you point to these two bullets?

MR. PIRES: Okay.

MEMBER SKILLMAN: Is it 100 samples, 80 samples, 500 samples?

MR. PIRES: Right, the project really reviewed what existed into analysis by themselves. But they reviewed 20 PRAs, 20 cycling PRAs. Some were done in the last ten years, other were done probably ten to 20 years ago. So there were already were the ways of doing the PRA during that timeframe.

The analysis methods that I used, yes several were reviewed. Some very simple method like what they call split fraction method, to more complicated methods like the Simex Safety Modular Research Program, then at Livermore. I don't know if you heard of that. Simex Safety Modular Research

Program done at Livermore, supposedly by the NRC.

Really involved defining for cut-sets, a joint probability distribution fraction. For the response in the capacity and then integrating the two together to calculate what was the probability of failure. Was a very complex and detailed approach, and that was used in designing PRA. So this addresses the second bullet. So that is more complex approach, and in many ways, the more rigorous approach.

And that yielded a set of rules. More complicated than the ones used now, but still simple. So we reviewed the entire scope of methodology that had been used and proposed.

MEMBER SKILLMAN: Thank you.

MEMBER REMPE: So later you cite the impact of those assumptions. And you do, as you noted in the first bullet, focus on CDF. What would have happened, you know, how important would it have been if you'd focused on the risk impact versus the frequency impact. Would you still have 30 to 60 percent, and up to a factor of 2 to 4? I mean are these important from a risk perspective as well as a frequency perspective is what I'm trying to --

MR. PIRES: In terms of the --

MEMBER REMPE: Of the studies you

reviewed?

MR. PIRES: -- risk of consequences, you --

MEMBER REMPE: Right. I mean are we looking at things that are not really risk important sequences? And okay, you say well it could be up to a factor of 2 to 4 for some of these sequences. And does it impact risk as much as it does frequency?

MR. PIRES: I think you're if you start -- right. This was outside the scope of the work, so I cannot really tell you. And also there are very few PRAs that have gone that far.

MEMBER REMPE: But you looked at those two or three, or whatever you looked at. And I'm just wondering what was the impact on risk of those PRAs?

MR. PIRES: I would be speculating.

(Off microphone comment.)

MEMBER MARCH-LEUBA: Are you implying that different core damages have different risk, different consequences?

MEMBER REMPE: Yes, I mean okay, the frequency could, they're quite, this differences of frequency, or what they're giving values of, and so, yes, you can have core damage where you have a big release. And you can have core damage when you don't have squat coming out.

And that's what I'm asking. And are we focusing on something important or not is where I'm getting to?

CHAIRMAN RICCARDELLA: But do seismic PRAs address that, or that they just compute a --

MEMBER DIMITRIJEVIC: Well core damage frequencies, least measure. It just will at least measure the large release frequency for example. Not too many seismic things went to the Level 2, or Level 3 that you can compare it. That's at least my understanding.

MR. PIRES: And the regular --

MEMBER DIMITRIJEVIC: And they're only special things. Because those frequencies, also these measures, so it's a large release which is next running through the consequences, and then you have a Level 3, which is, you know, public release which is different thing.

But the seismic so far, I mean I only saw core damage frequencies, but I'm sure that now new ones are also producing land releases, right?

MR. PIRES: I think so.

MEMBER DIMITRIJEVIC: Yes, yes so.

MR. PIRES: Now they are.

CHAIRMAN RICCARDELLA: What was that last point? I missed that.

MEMBER DIMITRIJEVIC: I think that those sites will now, when they're handling this seismic PRAs is a part of this 2.1 initiative. I think they are going to the large release too.

CHAIRMAN RICCARDELLA: Okay.

MEMBER DIMITRIJEVIC: But I don't know the ones which you reviewed, these 20 PRAs, did they have releases?

MR. PIRES: The one I, no they did not. Some of the ones that -- one of the PRAs that were more complex were the NUREG-1150. You know, some of those went to large, to releases, but not for seismic. The seismic part ended before that, was not continued all the way there.

MEMBER MARCH-LEUBA: Because for that you would have to consider correlation between this C pumps over here, and failure of the containment.

MR. PIRES: Yes.

MEMBER MARCH-LEUBA: And you will have to consider that correlation on top of the other one which is already a difficult to have.

MR. PIRES: I don't want to steer away from the topic, but some of the multipatient from the study back in 2010 time to '12 timeframe was the SOARCA study. Because you had some sequences and eventually the containment, there would be a release and others. And so but in the end, were never used there obviously.

The report work was turned in before and that was not the risk study. It was a severe accident, yes. So you can see that, yes, it was along those lines. Also you have to bring evacuation issues, relocation issues, and there those are also another type of problem. And at this moment NUREG-1150 been stopped before, before that part is external hazards.

And this, I talk a little bit about the analysis aspect because we keep talking about the methodology that somehow was proposed. And might be better. And I felt, don't want to delay that too much before going back to some of the review of the literature.

And so it might, I think what the authors, if I could put myself in their frame of mind, the way I understood it, is that so these dependencies really arise on the system analysis part of the -- when you do the fragility analysis for a component, you don't have this issue. You're talking to a single component there.

So in the system analysis sometimes you would have a set, or a subsystem that involves various components, and the performance of that subsystem is a Boolean expression. Simplest one would be the series, the components in parallel, where if you assume dependency, it will be an upper bound estimate. Those are the AND gates. And OR are the ones in series, which is the converse way, that is simple.

So in the end what you really get out of that is a fragility fraction. Even though much has been the fragility of one of the components. Or a multiplication of the fragility, but you really get a fragility fraction that represents that subsystem.

So the multipatient of these researchers was a --

MEMBER RAY: Wait.

MR. PIRES: Yes.

MEMBER RAY: I waited to ask a question before you changed that slide.

(Off microphone comment.)

MEMBER RAY: Well, I thought I'd pressed it but I didn't, hadn't. This is a -- I started to say an unfair question maybe, but nevertheless I've got to ask it because it's hanging on my -- would you, in talking about the AND gates, structures and some components in parallel. It makes me think as somebody who operated plants for a long time, what do we assume, or is it relevant to even think about what the tech specs require in terms of, being in service?

In other words, I've got three pumps but I only have to have two of them in service. And I can take one of those out for a week. Does that ever enter into these analyses? Maybe Mehdi could shed light on that --

MR. REISI-FARD: The short answer is yes. So the reliability or availability numbers that are already included in PRAs, they do take into account, you know, taking certain SSCs out of service for a period of time. So the numbers in the PRAs, the availability numbers in the PRAs take into account that factor.

MEMBER RAY: Okay, and that's good to hear. I assumed it wasn't germane to exactly what we were talking about here, but nevertheless it was a question that I had because systems required to be in service is sometimes a real burdensome requirement that people back away from in actual practice. And that's what I was interested in.

MR. REISI-FARD: And I used the word

availability, I should have said, unavailability.

MEMBER RAY: Yes, well that's fine. Thank you.

CHAIRMAN RICCARDELLA: And just help me on that first subbullet that you have the SSSs. Is that a typo, is that supposed to be SSCs?

MR. REISI-FARD: Yes.

CHAIRMAN RICCARDELLA: I just wanted to make sure we weren't introducing a new acronym here. I have enough trouble --

MEMBER REMPE: Wise.

(Off microphone comments.)

MR. PIRES: Sorry. So what was, what's done here was to try to say okay, this is, these dependencies issues are right, getting the system analysis process. But in the reality what you are trying to do is that for that subsystem where the dependencies may be significant and important, you're really trying to calculate a new fragility fraction for those. It is essentially what you are doing that those sets of rules are doing that, using what fragilities that you already have.

So the approach was to see okay, what, how are these fragility fractions calculated for each component? And then break down the process into various factors that have some physical meaning or engineering meaning, so that you more easily would be able to break down what are the parts that would likely be correlated there. So that was the approach that was done here. And so then the methodology could then provide this spectra between fully correlated and independent.

I tried to put here something just to try to show what I just said. And I'm not trying to come much more intent in terms of these equations, but in the seismic fragility, normally is expressed in terms of a ground motion level. A, so it is expressed in terms of the median of that ground motion level, that in this case represents the capacity of the component. Can it resist that ground motion level?

And then two random variables, one they will refer to it as the random uncertainty. And the other the epistemic uncertainty. And normally this process is simplified by saying that the fragility can be expressed in terms of effect of safety, times a reference level earthquake. The spectra of safety is really just scales of these, but it's just a convenience. Now --

CHAIRMAN RICCARDELLA: The reference level is like SSE, or OBE?

MR. PIRES: Could be the SSE, or OBE, or at the given as a level, being say, the ten to the minus four if you are talking about, if we think the dominant being, would be around that level, ten to the minus four, as a -- this, so you have that factor of safety.

So it is component, capacity, components and it is seismic response components, and those are even further broken down into either the capacity as some, these are strengths. The other is the ductility.

The partial factors for the seismic response have many parameters like the uncertainties on the spectra of the ground motion. How you combine the mode shapes, to the substructure direction. So the transfer function that brings you the ground to the various floors that you asked about.

So what this method does is that if you have various components in that cut-set, in that Boolean expression A, B, C & D. You are going to try to find out what is the correlation coefficient on those uncertainties. When you got to the epistemic uncertainties that are, what part of those uncertainties between A&B, and B&C and D is really a correlation coefficient, the co-variance?

CHAIRMAN RICCARDELLA: Could we go back to the previous one, and just help me with what all those F factors are on the bottom.

MR. PIRES: Right, I know this is a bit hard.

CHAIRMAN RICCARDELLA: I understand, you know, capacity and response, okay. But then the next one, are you saying that the capacity breaks down into that F sub S, and F sub U?

MR. PIRES: Yes, that is the capacity they -- it is for fragility analysis not for design. Is that if you have for instance a sheer wall on a building, you know what the distress of that sheer wall. But you know that it may have some ductility. And so because of that ductility, it can actually take higher seismic loads. Not just the ones that goes to the region that's strained. So the analysis is rigorous and accounts for this.

I don't want to make your discussion on all the fragility analysis done, but that it has all these factors appear there. So when the analyst --

CHAIRMAN RICCARDELLA: Just tell me what some of those subscripts stand for.

MR. PIRES: Okay, so the first one on the response factor, the first one, SA, stands for the uncertainties on the response factor of the ground motion. If you have a frequency, say 5Hz, you know what is the median value of the spectral acceleration. But there is an uncertainty about that.

CHAIRMAN RICCARDELLA: Okay.

MR. PIRES: So that they are accounted there. D is the damping. We may not know as well the damping of the structure as we think we know. M, now I'm a little worried about what this M, I forgot, but it will probably come back.

But MC is the model combination rule that you use. You have to combine all these mode change. EC is how you combine ground motion in different directions, because the earthquake goes actually in all directions. You know, you just cannot do an analysis for one.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: And so that's EC. And SD is the depth. If the structures are embedded, you know, you normally tend to reduce the forces on the components but there are uncertainties also. That also brought uncertainties.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: And the SS is the soil-structure interaction. You know, when you interact the structure is not in -- it couples with the ground and some energy is radiated away --

CHAIRMAN RICCARDELLA: Right.

MR. PIRES: -- and changes the resonant frequency. So these are factors that appear on the calculation of the response. Every one of those has a random uncertainty and epistemic uncertainty.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: And so what is the first is trying to do here? What they try to do is if you add several components, a component A and a component B, or a B and C, a component B and a component C, you will try to see on that ER and EU, what part of that uncertainty between those two components is really correlated?

And so you will break down the uncertainty into correlated and then what it is for the component itself is independent.

MEMBER MARCH-LEUBA: Since Pete brought the math, why do you combine the certainties in a multiplicity of sense, instead of being like the sum or the sum of the squares, or -- does that make sense?

MR. PIRES: The uncertainties are going to the sum of the squares.

MEMBER MARCH-LEUBA: I thought they

weren't.

(Simultaneous speaking.)

MEMBER MARCH-LEUBA: Well, those Fs are not uncertainty?

MR. PIRES: Those Fs are not the uncertainties.

CHAIRMAN RICCARDELLA: Those are factors.

MR. PIRES: Each one of those Fs is equal to a median times two uncertainty factors. One for random, one for epistemic. So those Fs are the factors themselves.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: And that factor is now, F, those factors, each one of those factors has an expression like the first one above.

CHAIRMAN RICCARDELLA: As a mean plus a distribution.

MR. PIRES: Plus two factors on all you vary around the mean.

MEMBER MARCH-LEUBA: Okay, so there was a reason to the madness, and I believe you.

MR. PIRES: Right, right. No, it is the way to account for all those factors there. So until the uncertainties on all those are combined into the sum of squares, and the square root. And essentially what the method is trying to do is really almost like finding a set of accumulating dependent random variables in which they try to separate what is correlated from what is not correlated between pairs of components. But without necessarily throwing away uncertainties. Still trying to preserve the uncertainty, but allocating it.

Now if you go and allocate the uncertainty at the high level there on the first line, that may be too abrupt, may be very judgmental. The idea of allocating the uncertainty through this method is that each one of those components you may have more engineering insights, to say what is to be correlated or not. For instance in the response we can actually have an analytical way to somehow calculate correlation. And the capacity is more difficult.

MR. PIRES: All right, so I move forward. And now, what are uncertainties on this process? So this process demonstrated in the report for various cases. But the report really does not go to the, starts more or less focus on the first line there. They don't go into detail to the bottom line, but that's necessary. So I just want to mention that, why it is necessary?

Because of the uncertainties, because and different analysts may come up with different results. So the more you try to break down and things limit you, you have really engineering understanding and meaning.

So, all you allocate what is correlated on the uncertainty, to what is independent is subjective in some ways. So there is engineering judgment. But if you break down to those basic variables, and then mathematically bring them back up to the higher level, you have a process that is more transparent, so to speak. That's the intent here.

Now, talk a little bit about the parts of the study. So the review of the SPRAs was processed. The impact of the assumption, the predicament of dependencies. And the conclusion there was that almost all SPRAs have used rule-based approach. And simple rule-based approach is perfectly correlated, totally dependent, and can date sensitivity analysis of those.

There have been a few exceptions, like I mentioned before, the Zion SPRA is an exception on the Seismic Safety Margins Research Program. So a very, these were done in the late, early, 70s. So there was a lot money to do these research projects, and we were learning. I mean what we do now, we learned from those projects.

And the Diablo Canyon SPRA also uses more complicated set of rules. It essentially started with the SSMRP approach, and then simplified to those rule-based approaches, but not just a direct use of them, more complex.

And so reviewed ten SPRAs. I think I told you 20, but it was a mistake. It was only ten, and that is the CDF range, so there was a broad range of CDF and the conclusions were those that sometimes there was a difference by a factor of two. But the more typical difference in the bottom line number is 30 to 60 percent. But some specific accident sequences could be more. And so the, for several SPRAs there really was not much of a sensitivity of the result to the dependencies.

MEMBER MARCH-LEUBA: Remind me again on that first bullet the factor of two, are 30 to 60 percent, is that by setting all correlations to one and all correlations to zero on the difference?

MR. PIRES: Yes.

MEMBER MARCH-LEUBA: Good. Thank you.

MR. PIRES: Great. Yes, and the --

CHAIRMAN RICCARDELLA: 30 to 60 percent on CDF?

MR. PIRES: On CDF. But on particular sequence is, and this where we talk about the insights, is the factor was high and it could be two to four.

MEMBER MARCH-LEUBA: Well, there are sequences that don't really contribute that much to the final numbers, is that correct?

MR. PIRES: Or there may be more than one sequence that contributes. There may be three or four sequences that contribute and the others are not so sensitive.

The cases normally where the dependencies were not significant, or the cases where there was a sequence that controlled the CDF and one component on that sequence. But they call it a single -- apparently that's the term they use. And those happen. It's --

MEMBER MARCH-LEUBA: Can you give us an example? Where will be the single component that is the dominant?

MR. PIRES: I can't tell you an example from my sequence --

MEMBER MARCH-LEUBA: From the many plans?

MR. PIRES: Yes, from a pilot study that EPRI did. I think in that plan that there were some sump pumps, there were actually several, but they all are damaged by the collapse of the building. And so, and those apparently were the main factor from --

MEMBER MARCH-LEUBA: So the collapse of the building is the single --

MR. PIRES: Yes, and damages all of them. That's the assumption. We already know by the way, that buildings not all collapse entirely but that there are parts of a building may collapse, others not, but that was a refinement that was not used and is not really used yet and I think that was one of the cases. But I may be wrong but that's my recollection.

MEMBER REMPE: So --

MEMBER MARCH-LEUBA: I think it's a work example.

MR. PIRES: Yes.

MEMBER REMPE: Years ago, I used to work for a company that had a paper reactor design. And so when they did their seismic study for the paper reactor design, they could get the release because they would just assume, look for the release of the sequence of with all those components failed.

Like in the Zion PRA, it seems like one could go back to the nons, the regular PRA and get those releases for those sequences that were deemed to be important here. If it's only a few sequences that are important, I think you could get some insights on is this important to risk from the information that is available.

And so I guess I'm still pushing. I think it should be explored. Are these things really important to risk if it's just 10 PRAs and a few sequences in those PRAs?

Is, I don't know how, I've seen some of the Zion one and some of these PRAs that seems like one could find some of that information.

MR. PIRES: Yes. I think you could find a nice, I'm pretty sure the authors of this study will know some of that information because they deal with these issues predominately and so they will know some of that.

And the, a lot of these, the benefits of some of these may be more for new designs because what already exist there is we don't have much in terms of what to change.

The, so one of the interesting parts of those reviews was that it looked like there was some set of components that tend to keep appearing on as being critical and some are relevant for these dependencies.

And they identified in the study, identified if you are listing them there. I don't want to go in more detail other than to say that they, the workshops also questioned the participants to force them to say what are the aspects of those components that really may make then really be more or less significant in terms of dependencies. For instance, the tanks, they tend to be fabricated locally so there are some variations actually.

So in that regard, in terms of the capacity, there may be some independence. But when you have some things fabricated in a factory and put together there may be more correlation between them. However, the anchors are done locally so that's more uncertainty.

So but they're at least collecting some input from experts there. Now the review of the literature like I said before, all the methods were reviewed. I'm not going to go here over all the methods. I don't think there is a point in doing that. I just like to provide a broad scope.

Of course the more rigorous one was this SMRP approach in which equity joint distributions were done for the capacity and the demands for components in a cut-set or in a Boolean expression and those were actually numerically integrated over the failure region and they were used in design PRA.

One of the benefits of that was that one of those authors of those studies, Mr. Bohn and Mr. Lambright, both of them, but Bohn seems to have been the name which will be associated with it, came up with rules that people use and that were simpler.

And but those rules were even deemed too difficult and too complex so they're further simplified.

I just show you the rules here. You can see that in some points these rules, these correlations coefficients of .05 and .75, those were abandoned in the current practice. People went back to minus zero.

MEMBER SUNSERI: This is a more complex set of --

MR. PIRES: A more complex set of rules on rules. But even this complex set of rules is not used in practice.

MEMBER CORRADINI: Because it's too complex?

MR. PIRES: And to that point I think was because probably the effort needed did not justify the intended use of the results, of the PRA, I think.

But now that of course as the odds have increased and so forth, so in some cases it might be more important to do, to at least bring some of those aspects into place.

So when they study and review of all the approaches, they come up that these older approach by Mr. Reed and McCann -- by both of them, mostly Reed, you won't find McCann on these there -- that this approach based on what I described before, it goes back to all the fragility and models done by the component.

All those factors are isolated and get out from there, because some of those factors, mostly you have some engineering meaning and there's an understanding of those, you could separate what could be correlated from that, but there is still subjectivity. There is still room for some judgment there, so.

But and it's not very difficult because you essentially are going to really, you already have that information from the fragility allowed for the components, and you can program the process that is there and implement. So there is an advantage.

In my opinion, of course, because there is some room from subjectivity there, it is the more you break down in the basic components and then work up from those, the better. The other is that the method is simplified so may warrant the comparison with more rigorous methods which exist, but they are very complicated but are used in practice. And that is not really the object of major research. That's just a graduate student master's key system.

The other part was review of existing data and I guess initially the researchers taught that there could be, it would be possible to get data so that the approach would be a more data-driven approach but it is not possible. The data is just not there and it would be very extensive.

MEMBER CORRADINI: Because it doesn't exist or because it's too complicated to analyze?

MR. PIRES: Both. No, the aspect experience data is too complicated to analyze. There are a lot of uncertainties on those. And so far, it has been proven very difficult. You know, the access to the data plus the uncertainties.

MEMBER CORRADINI: Is there other industries that care enough about seismic response that this approach has been taken or a simpler approach has been taken?

MR. PIRES: Yes. There is a, actually, in our work, there is an approach that relies a lot on -- experience data.

MEMBER CORRADINI: Say again, please?

MR. PIRES: In the nuclear power plants, I don't know if you ever heard about seismic liquefaction, soil liquefaction --

MEMBER CORRADINI: Yes.

MR. PIRES: -- during an earthquake. Ultimately, the approaches for soil liquefaction are experience-based. There is always even, because it is your technical problem involves soils and so forth. The laboratory samples are typically very small.

There is a large effort to connect to an experience data. And the uncertainty still is large and disparity of many disagreements on authoring that data, but it has become necessary to do that. So that's a success story on use of earthquake experience data.

MEMBER CORRADINI: What I guess I'm trying to get is, is there, I'm trying to connect back to your multifactor formula --

MR. PIRES: Okay.

MEMBER CORRADINI: -- which is some sort of benchmarking of the approach that might be used in difference to the heuristic rules that are currently used.

MR. PIRES: Yes. I think the benchmark, it probably would have to be done with shake table testing data.

CHAIRMAN RICCARDELLA: I think the problem with shake table testing though is that in equipment qualification, you don't shake it to failure. You just shake it up until a certain level. If it doesn't fail, it passes and you're done. So you really don't get any data about correlation or even about the failure level of a piece of equipment, right?

MR. PIRES: I think that's one of the issues of the test data on shake table. The more the fragility analysis is amenable to analytical approach is the easier it is to use this methodology. But equipment, sometimes that not so easy to do.

CHAIRMAN RICCARDELLA: Yes, oh yes.

MR. PIRES: You know, for some equipment changes you can do analysis, but for other equipment you cannot do that. One possibility would be to, there are very large shaking tables of detail that maybe while there you could put multiple components on the shake table, orient them in different directions but you see that they have collect data. But that's --

CHAIRMAN RICCARDELLA: You still have to shake them to failure, you're not --

MR. PIRES: Right, you still have to shake that to --

CHAIRMAN RICCARDELLA: You still have to shake them up to a certain level and nothing fails, you don't learn anything, right?

MR. PIRES: Yes, you will need to shake them to failure until probably all of them are failed in the table. And that would have correlated ground motions but then you should isolate the capacity part though because you --

CHAIRMAN RICCARDELLA: Yes, yes.

MR. PIRES: But to do that, you have to have adjudication in that is it necessary to do that for the use intended? But that will be, for some of these aspect experience, in some cases you can find the information but is not common.

MEMBER CORRADINI: So let me ask the question from a justification standpoint. So I thought your slide number, maybe I misunderstood the conclusion you had in the slide, which was Slide 19, which is it made a 30 to 60 percent difference on CDF.

MR. PIRES: Well, it --

MEMBER CORRADINI: Typical difference in

the range of 30 to 60 percent.

MR. PIRES: Yes.

MEMBER CORRADINI: So is that enough of a difference to warrant this, excuse my English, complex analysis approach?

MR. PIRES: It depends on the use of that result. I think it, I, you know, if you start going in terms of the total risk or are you just separating the risk for each seismic cause, simple seismic causes?

MEMBER CORRADINI: That last part, I'm sorry?

MR. PIRES: Suppose you are interested on the total risk for the facility, not just from the seismic concept which I understand could be between five to 50 percent of the total risk in terms of CDF. But now you start bringing the fire, you start bringing the internal events, and higher range, and combining all the hazards together. Then you get that risk that you may need to see where can you obtain a more accurate results and so that you can open risk inside safety insights --

MEMBER CORRADINI: Okay.

MR. PIRES: -- and to address that. So in those situations I can possibly see that that could happen for an operating plant but I've not seen any case like that.

MEMBER MARCH-LEUBA: This is not unusual for this application. We see this in the nuclear industry, especially on -- an example I always mention is over pressure events where you analyze how close you are from the level C. All plants are like two PSI from it because this started first with a cheap analysis. You ran it, good. A cheap conservative analysis. You run with it you stop.

If you fail, you go to a more sophisticated analysis. You fail that one, you go to even more sophisticated analysis until you pass. And all of them are perfectly good analysis so this is a similar thing. So this will be only applicable for plants that are close to a limit and where 30 percent makes a difference.

MR. PIRES: Yes. It, and typically when, Mehdi is here, he can correct me. I went to a meeting recently in which there was an issue and obviously the hazard is low and the plant was designed, the job is design it for a minimum capacity. In that case you probably don't need to do these things. The other is very high and like in the, that case of Diablo Canyon, all of the studies were done in some level of rigor.

If some of those plants closer to that higher hazard situation in which the original design might have missed the hazard, that would have more critical. Otherwise it's new designs.

MEMBER MARCH-LEUBA: And my personal philosophy, preference if you want to, and so for spending the money doing an analysis, going forth with some of those components and make them better. Spend the same money and Well, just spend the money on paperwork or actually reinforced beams, put some reinforced beams.

MR. PIRES: Well, what the analyst can't tell you is what each wants to do that.

MEMBER MARCH-LEUBA: That is where the value is.

MR. PIRES: Yes, that would be the value because it's not expected that there will be many if that case would happen. I've not seen any case but the analyst could tell you which one of those.

MEMBER MARCH-LEUBA: You know there is going to be cheaper to bring forth a couple of components, rotate them 90 degrees or whatever, than doing all the paperwork.

MR. PIRES: In the end, you will end up with capital investments that can do that on some components and I think these analyst can identify those.

MEMBER MARCH-LEUBA: And while it would on this, NRC will not reward you for doing the right thing, just reinforcing those components. There are so many questions about it, whereas if you come up with the paperwork analysis, they'll let you go through.

MR. PIRES: But I have seen that in some cases, people somehow identified what risk contributed but maybe possible single tons, I don't, can't be specific but that somehow might have led to some upgrade.

MEMBER MARCH-LEUBA: Yes. As an example, I always say that if I am operating a plant, I will mount two diesel generators. One in the basement and one on the fifth floor. The fifth floor will fail in an earthquake, the basement will fail on a flood but at least I'll have one left.

MR. PIRES: Right.

MEMBER REMPE: So if you were going to use this for insights on which components to reinforce, I would then say you need better data. So if you go back to Slide 24, you talk about that the data from actual earthquake experience in the plants is sparse because people are only reporting failures, or a few failures.

I was wondering if one would take a different attitude. Maybe you ought to also be documenting which components survive as well as the ones who fail.

I think, again, I'm more into, yes, I'd like to upgrade the plant but also before I go and do more on data or on that modeling, I would really focus on what could you learn from the real world before I get a model. And so it seems like you could do something that way.

MR. PIRES: That is done. The aspects that go and collect aspect experience, they collect both types. Do you remember that meeting in North Carolina about a year ago and in which there was a person proposing more collection of earthquake experience data and more analysis of that? And he emphasized and he has done that in practice for industrial facilities like fossil power plants and the others, and they collect both data. They collect data that survived and data that did not survive.

MEMBER REMPE: Yes.

MR. PIRES: Most types of data are collected. And but I think in this case, the reference to the, to where you might want to do some capital investments is for those cases where you could see that that would have a big payoff to these sensitive analysis.

MEMBER REMPE: The sensitivity with the old current models. I agree on that one, but.

MR. PIRES: Or even with even with improved models, it's, but probably that's of course my opinion.

MEMBER REMPE: We all have opinions, I guess.

(Laughter.)

MR. PIRES: Right. But probably more value of these and I move the, if I may, move to the other slide. This is how the author recommended that all these would be used so they would still start to be the, perform SPR using the standard methods, enough sensitivity studies so that you can see what, where you may need to make refinements, then the identification of those cut-sets or sequences where you would want to make this refinement of the methodologies.

So these are systems analysts there in red. The one in blue, that would be now back to the fragility analyst that would then go use these methods to revise the fragility calculation for those cut-sets to obtain numbers that was the methodology that is referred to here.

And then we'll go back to the SPRA analyst and do the work. So that would be a process that could be done.

MEMBER MARCH-LEUBA: So if you only propose to do this analysis for the two or three cut-sets that make a difference, it's not that expensive.

MR. PIRES: No. But you need to have a good analyst.

MEMBER MARCH-LEUBA: Yes, well, that's where the big bucks are, right?

MR. PIRES: Right, yes, maybe. And so you have here that, so there are difficulties here with the analyst and for this revised fragilities that appear on the blue box and it is, there can be variability among fragility analysts and the report mentions that.

(Off microphone comment.)

MR. PIRES: And there is still some level of expert judgment. I think by breaking down on the basic variables like the fragility on all these tests, you reduce some of that judgment quite significantly

I think. Because it's more transparent to the process where you get to the breakdown of the uncertainties and so.

(Off microphone comment.)

MEMBER CHU: The airplane mode works.

CHAIRMAN RICCARDELLA: Airplane mode works, yes. I never said, that's not me.

MR. PIRES: And so this is, let me see, so I don't know if somebody remarked that essentially it's just a summary of what we have been discussing about it. I don't know if you want to go through them again.

But one item that I would like to say there, is that this, we think that with this study we can maintain a dialogue with the industry. If the industry's interested and go into other, you know, more refined methodologies. We already, it's essentially our part and now the industry probably, they are interested. They can either pursue this part or others because we already did some staffing say that there is some things that may have promise.

Now with the, you ask that the, so the treatment of dependencies always depends on the intended results. So we are not implying here that what is being done now is not appropriate or correct.

And part of the demonstrations of methodology would be necessary like you said. It's just the start of a dialogue and there can be arising needs. And like you mentioned, the Chairman mentioned at the beginning of the meeting, maybe modular reactors or advanced reactors may want to consider these at the early design stage.

I understand it's not being done now because the design certification process is, there is not a lot of definition yet but that is a choice of the applicant.

And so we want some of you prepared if the applicants go that way. They, our knowledge can respond to that and now understand it.

MEMBER CORRADINI: Or they could just make a more robust structure so that the residual risk is small enough you don't care.

MR. PIRES: Right. But that is there to be their choice.

MEMBER CORRADINI: Yes, okay.

MR. PIRES: And but the point is, one I can hear is that you may keep adding more components and not really have much benefit in terms of the redundancy that it will bring up.

So you can from the very get-go design

that to get that redundancy so that they will not have a dependent failure.

MEMBER SKILLMAN: Two or three times around the table, members have mentioned that maybe the ticket here is to make a robust structure. And I've been involved in Europe and in the United States where the exact opposite was the right thing to do.

We actually weakened the structure. We made sure that the earthquake went under the structure and the structure didn't respond and so it can go either way.

And it boils down, at least in my mind, this whole thing boils down to a probabilistic risk assessment that identifies those structures and systems and components that are credited for success for the specific accident.

In one case, it might be the batteries. In another case it might be high pressure injection pump. In another case it might be the high head safety injection pump in a boiling water reactor. So it's scenario specific, it's plant design specific, and it is condition specific.

Like Harold said, like I said early on, you got to know the tech specs. You got to know what's credited. You got to know which systems are aligned for what purpose and when, when the event occurs.

That is part of this rubrics to get a path forward that allows examination that is meaningful in terms of what Dr. Rempe said, risk, not just a failure of the device.

You know, you can fail the water cooler, you can fail the front door of the administration building, but you don't want to fail the nozzle that puts the water onto the fuel.

The risk is associated with the right component, in the right place, at the right time for the particular accident and the particular ground motion. All of those are pieces.

CHAIRMAN RICCARDELLA: Core damage frequency can't capture those differences though.

MEMBER SKILLMAN: Pardon?

CHAIRMAN RICCARDELLA: Core damage frequency can't, I mean, the water cooler and the door to the admin building isn't going to impact core damage frequency.

MEMBER SKILLMAN: My only point is, my only point is, it's very component-specific.

CHAIRMAN RICCARDELLA: Yes.

MEMBER SKILLMAN: Your risk is very, very component specific.

MR. PIRES: I think the least that they showed here on the workshop as a result of the workshop and the review of past PRAs, mostly the components are of course are not buildings. I guess we knew that, they, this is the type of component that typically appeared there as critical.

Of course the building's response affects those because the way it amplifies the ground motion. And when people talk about seismic isolation, they could review some of these.

MEMBER CORRADINI: So let's talk about seismic. You brought it up. I was going to but you first. Tell me about, I was under the impression there is a potential standard that, a potential approach that's been in front of the staff to look at for seismic isolation?

MR. PIRES: No, no. No, no, no. There is a standard --

MEMBER CORRADINI: You did it. I didn't do it.

MR. PIRES: Right. No, I know.

CHAIRMAN RICCARDELLA: There was a DOE research part.

MR. PIRES: There is a standard. There is an American Society of Civil Engineering Standards that has a chapter there on Seismic isolation.

And we are not necessarily reviewing that standard for seismic isolation. We are reviewing that standard for many other, in terms of for more risk, and from approach, performance based to the seismic design, but not necessarily that particular part. We have other research projects on seismic isolation already at the Agency here and so we have to look at those.

MEMBER CORRADINI: Well, what I guess I'm --I'm sorry, I didn't mean to interrupt you.

MR. PIRES: Sure.

MEMBER CORRADINI: Go ahead and finish, I'm sorry.

MR. PIRES: No, we have other research projects but not necessarily aimed at reviewing a particular standard but aimed at developing technical consideration that should be accounted for when designing seismic isolation systems.

MEMBER CORRADINI: Well I guess I'm a bit unsure what you just said. So is there a standard in front of the staff to evaluate or is it still a matter of research?

I thought there was a standard in front of the staff that the staff is evaluating, the suggested standard from the civil engineering society.

MR. PIRES: There is a standard but we are not ever tasked to evaluate that standard.

MEMBER CORRADINI: We --

MR. PIRES: We do not have a task to evaluate that standard, but --

MEMBER CORRADINI: So there's not been a request yet?

MR. PIRES: Not been a request. Yes, there's not been a request. We are reviewing that standard but that standard has so many other aspects, those are the ones we are doing.

But we have independently done research that develop technical considerations for, that should be accounted for if seismic isolation were to be used in a nuclear power plant design. So we have independently done that ourselves.

MEMBER CORRADINI: But if tomorrow, if reactor X comes in, a small modular reactor, and says we're going to isolate the safety structures with seismic isolation, is there a standard they can follow that the NRC has approved or at least has reviewed?

MR. PIRES: No. There is not a standard that we have taken a staff position on.

MEMBER CORRADINI: Is there something that --

MR. PIRES: We have done research in relation to that.

MEMBER CORRADINI: So there's nothing that they can point to that is yet to be reviewed but could be, or is it a matter of research or is it a matter of working through the standard that is out there but yet to be reviewed and approved? I'm trying to understand where this is.

MR. PIRES: Right. All right. Our research project culminated in a NUREG/CR contractor report that does technical considerations for the use of base isolation on nuclear power plants. Those technical considerations are probably better than those in the standard.

MEMBER CORRADINI: Right.

MR. PIRES: This is of course our opinion. But they are very closely related in many ways. So actually our contractor was the one who brought most up to standard.

MEMBER CORRADINI: Okay.

MR. PIRES: So maybe I should not say this, but that does not mean that the standard per se is sufficient either. The standard may not be necessarily sufficient.

MEMBER CORRADINI: Okay.

MR. PIRES: Because there are several many other details and considerations that are not necessarily covered in the standard by that, neither by that NUREGs.

MEMBER CORRADINI: Because that's some --

MR. PIRES: It the variety for the details.

MEMBER CORRADINI: Well, I mean the reason I'm bringing it up is, one, you did but I was going to anyway, so I can't blame you totally.

MR. PIRES: Right.

MEMBER CORRADINI: But in other technical meetings there has been discussion that these advanced reactors, whatever they are, are going to try to use this to minimize to allow the structure to be more simply built --

MR. PIRES: Right.

MEMBER CORRADINI: -- because it has a smaller footprint. And so the next question has been, in some of these technical discussions, well, is there a standard? And the answer back is yes, but the NRC has not reviewed it.

That is what I've heard in technical

discussions.

MR. PIRES: Right.

MEMBER CORRADINI: And I'm trying to understand where the reality is versus what I hear in a --

MR. PIRES: The NRC has not reviewed and taken a staff position on that standard. The NRC has done research very similar to the research that supports the standard. So we are not at zero. We have a knowledge basis in Agency on that topic. So we can come --

MEMBER CORRADINI: But nobody has come to you to say we want to use this, can we use this? That's what I'm hopeful for.

MR. PIRES: Right.

MEMBER CORRADINI: Eventually.

MR. PIRES: We are not at that situation, yet. But we have done the research --

MEMBER CORRADINI: Okay.

CHAIRMAN RICCARDELLA: Yes, good.

MR. PIRES: -- that can take to that situation if that materializes.

CHAIRMAN RICCARDELLA: I recall a meeting I attended maybe three years ago at the Department of DOE. Did DOE sponsor a big program like that?

MEMBER CORRADINI: Yes, there was a study at DOE.

CHAIRMAN RICCARDELLA: You were there, weren't you, Jose?

MR. PIRES: Yes, DOE does have recent projects on that.

(Simultaneous speaking.)

CHAIRMAN RICCARDELLA: On isolation.

MEMBER CORRADINI: University of Buffalo. There is a large group at University of Buffalo. That's where I had the presentation and I --

MR. PIRES: He was our contact there for that project.

CHAIRMAN RICCARDELLA: Your contact.

MR. PIRES: For that same group.

MEMBER CORRADINI: Same group?

MR. PIRES: Yes. So we are up to date on what is happening in that world and obviously where if someone is going to submit an application, there are many, many more details than just the standard.

CHAIRMAN RICCARDELLA: Yes.

MR. PIRES: But we are up to date but we have not developed necessarily a staff position. That's, but we are up to date.

MEMBER CORRADINI: Okay.

MR. PIRES: We are not, which I think we are in a good position to be responsive.

MEMBER CORRADINI: Thanks for bringing it up.

MR. PIRES: You are welcome, yes.

CHAIRMAN RICCARDELLA: I have a couple of questions. I know there's these ongoing Task 2.1 seismic reviews of the CS plants and as I understood it, about a third of the plants out there had to take a new look at their seismic because they exceeded their current ground motion response factor, right?

MR. REISI-FARD: That's about the right number.

CHAIRMAN RICCARDELLA: Are those plants having problems? I mean they're doing SPRAs or seismic margins analyses. Are they having, are there any plants that have issues, are having issues satisfying the criteria?

MR. REISI-FARD: Not to my knowledge and this goes back to some of the discussions earlier about the level of detail or analysis that is needed to do the SPRAs.

For the purpose of this informed decision making, there is the SPRA standard out there which is being peer reviewed by, you know, there's a process for doing the peer review.

And they have been using, the industry, the licensees have been using these methods for a long time and, you know, it's been, their PRAs have been peer reviewed against the standard and, you know, it's just a matter of uncertainty, key assumption uncertainty in the model. There are no, typically there are not many findings associated with how the correlation is considered. They either assume full correlation or no correlation.

CHAIRMAN RICCARDELLA: Yes. Yes, I mean I would think kind of like what Jose said earlier, you only sharpen your pencil as sharp as it needs to be.

And so if none of these plants are having any problem meeting their, whatever the criteria are for their SPRAs then they wouldn't necessarily go back and relook at this. But if they do have an analysis or two that's giving them problems, maybe they might try to do it.

MR. REISI-FARD: And I know that's out of a few or several SPRAs that we've seen, there is only one exception that they've used a little bit more refined analysis. It's not using .05 or .75 or anything like that.

But because the licensee decided to have a look, it's more detailed final element analysis they have a better understanding of the seismic demand in different locations. So if there was a different seismic demand, they use different correlations. But other than that, they basically assume zero or complete correlation.

CHAIRMAN RICCARDELLA: Yes. So and then another potential application as I said earlier, is the NuScale or some new reactors where if you haven't completed the design yet, it seems like you could take some of this into consideration in advance and have it affect your design.

But, Vesna, the NuScale PRA that we'll be reviewing, does that include a seismic PRA?

(Off microphone comment.)

MEMBER CORRADINI: I thought it was a seismic --

CHAIRMAN RICCARDELLA: It concentrates on a --

MEMBER CORRADINI: -- margin analysis. I didn't think it was the seismic --

MEMBER DIMITRIJEVIC: Yes. I mean, seismic analysis -- seismic risk analysis is a new type. I think it's a seismic matching but it's irrelevant because the NuScale is submitted analysis based on the single unit.

CHAIRMAN RICCARDELLA: So --

MEMBER DIMITRIJEVIC: So it's irrelevant, do they have a ten, 12, or 20 units. They just analyze in single units. That's what their agreement with NRC, so we don't, we may see in consequence, but the consequence in this case means that, you know, Level 3 analyzes that some combination. But on the PRA, no, it's just a single use.

MR. PIRES: That's what I heard too. That currently it's a single unit and the seismic margin is what they call a PRA based seismic margin.

MEMBER DIMITRIJEVIC: Right.

MR. PIRES: But because that seismic margin approach and that the guidance really involves simplified methods, min-max approaches and that there. So it's not really --

(Off microphone comment.)

MR. PIRES: But can be used that, but is a simplified PRA based seismic margin and --

CHAIRMAN RICCARDELLA: But if they were to come in and try to license multiple plants at a site, wouldn't it be necessary for their PRA to address a multi-unit site?

MEMBER DIMITRIJEVIC: That's my opinion

but I jump on this train late and disagreements had already reached, I mean, with the staff. So, I mean, I will bring this question to the review because it's not just seismic, all other external ones, you know?

CHAIRMAN RICCARDELLA: Yes, yes, of course.

MEMBER DIMITRIJEVIC: You know, like external floods and which is one of the main important contributions. But that's what is put into that so. They have a multi-unit on the license but that actually involves the analysis from ability that two units fails. That didn't include the seismic common cause, it just includes the single, the single non-seismic common cause between each. So we will have a discussion about that but that's --

CHAIRMAN RICCARDELLA: Okay.

MEMBER DIMITRIJEVIC: It doesn't say if you have a challenge, what's the probability of one of 12 things with that.

CHAIRMAN RICCARDELLA: Yes. That's coming up this month, right?

MEMBER DIMITRIJEVIC: Yes, and this analysis is happening in the next --

MEMBER CORRADINI: The first meeting will be this month.

MEMBER DIMITRIJEVIC: -- yes, yes.

MEMBER CORRADINI: It won't be the last meeting.

MEMBER DIMITRIJEVIC: No. Right, so.

CHAIRMAN RICCARDELLA: Okay.

MEMBER DIMITRIJEVIC: Well, and I have a microphone on. I have one question. In your report there was some example identified with three service water pumps show as important.

You know, when we have a seismic, we always assume that we have a loss of onsite power as it normally is out and then these generators as you mentioned are important, but, and but they cool the service water so service water is important.

And usually single structures or tanks like lube oil tank can dominate what is used at the generator if you don't know correlation, or intake structure when it's the pumps itself.

But there was an example reported in that report of the sump cuts, actually the three service water pumps.

CHAIRMAN RICCARDELLA: Yes.

MEMBER DIMITRIJEVIC: The three service water pumps show it's very important in that site meet PRA but then they didn't proceed with how did they solve that issue?

MR. PIRES: The one I referred to was a pilot study so it was not really tied into any particular licensing issue or not.

(Simultaneous speaking.)

MEMBER DIMITRIJEVIC: I see.

MR. PIRES: It was a pilot study.

MEMBER DIMITRIJEVIC: It could be, yes, is the early ones when done and then they tried it, yes. I understand this.

MR. PIRES: So it was a little different, the use. Well, in principle this methodology can be useful modular reactors and but again it also depends on the problem statement. What would it be used for? What would be the intent to go all the way to releases, to one model fails, all fails, do they fail simultaneously? And do they need safety systems from another? Are they relying on safety systems from another core module to stop an accident progression on one of their modules and on their other model?

So I think depending on the problem statement is done, is what one they have to look, but in principle can be done. And if you had the analysis for the single model you can extrapolate it by the correlations using this approach. But it has to pay off, has to have a benefit for the applicant.

MEMBER REMPE: So when I look at the last bullet here I also go back to Page 26 and see all of the caveats you have about before you can be using this methodology and it seems like that there's a lot of work still to be done if one wanted to apply and use this as part of the standard tool kit available to seismic people. And I just kind of wanted to see you shake your head up and down, yes.

MR. PIRES: I think so. There is, there will be substantial work yet, but the question is at this point, like I think I mentioned before, I think we have done probably our part on the dialogue.

MEMBER REMPE: Yes.

MR. PIRES: And so maybe now someone else has to get that additional work and maybe we, put these points to some other organization that does research, that can be cooperative research but maybe will have a role. But if I think we only need to have now the initiative coming from outside.

MEMBER MARCH-LEUBA: This gets me thinking to the topic I wanted to change the conversation just as we have plenty of time and I know you've done all this because you've told me on the side.

MR. PIRES: Yes.

MEMBER MARCH-LEUBA: It's still bit of certainties.

MR. PIRES: Okay.

MEMBER MARCH-LEUBA: You told us that all of those F parameters on the long equation have their uncertainty but now you're splitting that uncertainty into two.

MR. PIRES: Right.

MEMBER MARCH-LEUBA: Yes. And the estate of the practice now is to split the CO1 by setting the correlation to CO1 and that term means what the uncertainty is. I know you've given some thought on how you would do the uncertainty with the proposed method. Can you talk a little bit about that?

MR. PIRES: How we would split this?

MEMBER MARCH-LEUBA: Yes. How would you, I mean, what is your, what was your consideration for treatment of uncertainties, the additional uncertainty that this introduce by the new method?

MR. PIRES: Oh, alright, yes. I think one of the bigger uncertainties to this, by the new method is this step that you just mentioned. How you are going to assign what is correlated and what is uncorrelated, particularly given that you don't have hard data.

And so but the study really did not look at that into detail because the study at this moment, they just, all the examples they have, they assign it the information to those things on the top line directly. They didn't even use the bottom line.

They just have statements. They are saying the -- interaction part of the building is not the same so if all components are in the same building, the -- interaction uncertainty probably is correlated.

But they have not really provided the metallic aspect how to go from the bottom line to the top line in assigning those uncertainties. So but I think that needs to be that. And if that, because of so many factors, they had all of these factors, they have many quality analysts, can eliminate much of the judgment, particularly those that can be done by analysis.

MEMBER MARCH-LEUBA: You know the field which was a very large study, 1980s probably, was the CSAU, Code Scaling, Applicability and Uncertainty Analysis.

MR. PIRES: Okay.

MEMBER MARCH-LEUBA: Anyway, called CSAU. The first step on CSAU is to provide a PIRT, Phenomena

Identification and Ranking Table, okay.

MR. PIRES: Right.

MEMBER MARCH-LEUBA: And all the thermal-hydraulics which are more of a deterministic instead of a probabilistic -- understood that because there will be, that you will get a different number, that he will get a different number.

So the PIRT always requests to have at least three experts in the field. And then you look at the variability between different opinions.

When you do the separation between ER and EU, probably will require at least a second opinion instead of just one guy.

MR. PIRES: Did, one of the things and the report mentions that they really recommend a peer review even if it is informal. Even if that is not a formal peer review that is required by a regulator or, they really recommend that you should have that.

But I think even before you get the peer review, you probably need the guidance on how to do that, based on this first step, it's to have that guidance and second is to have a peer review.

MEMBER MARCH-LEUBA: Yes, but in my mind, and maybe I'm biased, but I think the largest source of uncertainty will be a subjective evaluation of numbers and that Jose will give a different result than Josie.

MR. PIRES: Right.

MEMBER MARCH-LEUBA: And it will be, and I thought that you addressed that in the report by recommending a peer review or list, you get an idea what the uncertainty is.

MR. PIRES: Right. And the report recognizes that, recognizes that there will be variability among the analysts.

MEMBER DIMITRIJEVIC: And do you know what also is problem, there is not two. There don't exist two fragility experts in that. You know, an agility expert is very sparse. Like ten years ago all world was using just one. I mean, I don't know what's the situation is now but then --

MR. PIRES: No, there are a few.

MEMBER DIMITRIJEVIC: We're not going to find many too complex opinions.

MR. PIRES: There are a few and I think the breaking down of the problem allows that. In my opinion, the more you can do to some analysis that are having to rely directly on the use of data so you have a matching off the two, you are better.

MEMBER MARCH-LEUBA: Okay. Well, my point is in the report you've given some thought to it and you have addressed the issue, that this is a problem.

MR. PIRES: Right. It is an issue.

CHAIRMAN RICCARDELLA: You know, on this slide you've got two different things where you split the uncertainty. In the top line it's random versus uncertainty. But to me, what's equally significant on the very bottom line, the first part of the equation there, it's F sub C and F sub RS and do each one of those have an R and a U?

MR. PIRES: Yes. And then each one of the other F's has an R and a U. So when you, in the end you can have a square root of some squares that are about 15 times there. So it can be complex.

But the analysts are used to do that. They go to their training. Typically what happens is if a utility wants to do an SPRA, what I understand some of them did is that they contract a firm that knows how to do these and they do an example for a building and the components in there.

They go through all this process. They define templates, and then they can have other engineers that go through that process systematically for other components and other buildings and other aspects.

So they have a process to do that to minimize errors and subjectivity. But it still can happen because the next step is to assign what part of, if you have two components now of those all their Rs and Us, what is the part that is correlated, the part of a covariance is still just a variance for each one?

And that part is somewhat difficult but there are reasons and arguments when you break down to be able to move in that direction, and it partly depends on the importance of the problem and what you want to do with the results.

CHAIRMAN RICCARDELLA: Yes. It seems that there's an opportunity that if you're designing a new plant for a new concept, like these modular reactors, that there might be some very, very minor things that you could do at relatively low cost that would make things less correlated.

MEMBER CORRADINI: But you could also increase the risk of something else. You can't just change this, you would have to redo everything. If I took all of these things and orient them ten degrees different, then my fuel handling might change --

CHAIRMAN RICCARDELLA: Yes, right, right.

MEMBER CORRADINI: -- so that I can

increase the risk of a fuel handling accident.

MR. PIRES: Yes. In some of these aspects, you probably, you know, one exercise a day, so I'm just thinking aloud without really --

But ideally it would be to have a set of rules coming out from PRA studies and those set of rules, then give indications if you want to obtain redundancy, you need to do these things in your design so that the design not necessarily have to, or define the rules that, and then, but and those would be exercise PRAs to come up with those rules.

MEMBER CORRADINI: Yes, but I think but in --

MEMBER MARCH-LEUBA: For in --

MEMBER CORRADINI: If I might just say, I think your Slide 25 though is the one that I got -- you don't have to go to it -- but the one with your blue and red boxes. You don't do this for everything.

You find out where it's critical to do it and then you delve in. I mean, it's like Jose's example of where you want to sharpen your pencil and where it's good enough to do a simple analysis. That's what I took away from that.

MEMBER MARCH-LEUBA: What I think that Pete is saying is that when we do fire analysis and do the INC. We put one division in a different cabinet. We have four different fire enclosures for each division because we only, we put them only in one, we have a fire, we're cooked. Okay.

If doing this safety PRN and you find out that all your three sump pumps are on the same weak building, that tells you a problem that you maybe need two sump pumps in different places. And that points you to small changes that maybe are not expensive that make the plant better. Remove the single pump.

MR. PIRES: Yes, like you said, that box already there in the parenthesis, but presumably should be few of those where you have to do that and have a benefit.

CHAIRMAN RICCARDELLA: But I guess the first step would be to make sure that they consider the multiple units in the PRA. If they're not doing that --

MEMBER MARCH-LEUBA: Somewhere I've read that they just multiply times 12 the results of one. And that they assume they're fully correlated. That's what I read somewhere but you're --

MEMBER CORRADINI: Wait until the October 18th meeting.

MEMBER MARCH-LEUBA: Yes.

MEMBER REMPE: But if you do, I mean, it's what your point was about the ship already, or the train already left. There's a couple of things, again just thinking off the top of your head, not only do you have the issue that you might have three pumps in 12 units that all are not considering all 12 units in the common cause, but what about just that you've got 12 units in the same pool and a bowling ball approach where they knock out each other?

MEMBER SKILLMAN: Joy, we raised that question.

MEMBER REMPE: Yes, I know.

MEMBER SKILLMAN: We absolutely raised that exact issue.

MEMBER REMPE: Yes.

MEMBER SKILLMAN: I think we're in a different --

(Off microphone comment.)

MEMBER REMPE: No.

MEMBER CORRADINI: I would suggest we're in a different discussion, that we should wait until we actually have the --

CHAIRMAN RICCARDELLA: Yes.

MEMBER SKILLMAN: I think in a way we're in a different discussion but we're going after the comment that Pete made that I think is right on the money.

Early on, slight adjustments can provide great risks reduction, or great reductions in risk. I think that that's accurate and I think we ought to be thinking about that. Just a couple of very minor changes that can allow a very significant outcome for an event and I think that's accurate.

MR. PIRES: In this case, I think for the multi-module syncs, it was probably important to come up with what is the problem statement that, for the applicant that the applicant wants to address? Is, are they worried about releases or if using systems from another module to save one model? Or, you know, I think that now that the problem statement has expanded because you have all these modules there relatively close to each other, and depending on that then they would have to choose what they want to do.

MEMBER MARCH-LEUBA: But I would like to think that the applicant is already doing that. I'm sure whoever designed the plant, they're looking for the low hanging fruit. I mean, if we weren't under the review when it comes to ACRS, nothing can be changed. So what we need is to encourage the applicants to think things this way.

MEMBER DIMITRIJEVIC: But this is just to tell you it's also bad because actually they're not in parallel, they're in series. So fail of any unit is, you know, basically the failer. It's, you know, they're not in parallel. So if you look in the component combination, whatever fail that unit, if you want to fail the second unit, or fail only the one unit present the problem. So it's from a, you know what I want try to say, the units are in the series actually when it comes to the core damage frequency, so.

MR. PIRES: This may be a case where a release might make a difference because if you ever sourced them for 12 modules versus from one module, but I don't know. It's, I have no idea. It's a problem statement.

CHAIRMAN RICCARDELLA: No, we have some food for thought for our meeting in two weeks and we can ask the applicant then.

Well, Jose, I thank you very much for coming by and briefing us all and Mehdi, we appreciate it.

I'm going to go around the room. But first, is there anybody in the room that would like to make a comment?

Hearing none, we'll go to the phone line. Can we open the line please?

MEMBER CORRADINI: We'll wait for a crackling sound.

CHAIRMAN RICCARDELLA: Yes. So when the phone line is open, if there's anybody listening to this, in on this call, I'd appreciate it if you would let us know that you're there and you hear us.

MEMBER MARCH-LEUBA: I just want to take -- on the line. Let's go around the table.

CHAIRMAN RICCARDELLA: Okay. So let's ask the subcommittee members. Vesna, do you, starting with Vesna and we'll go around the table.

MEMBER DIMITRIJEVIC: Yes, I'm all right. I don't have additional questions.

MEMBER CHU: Nothing.

CHAIRMAN RICCARDELLA: Harold?

MEMBER RAY: To me, Pete, this is more input rather than a time for us to give feedback. I, you know, I think the issue always in my mind is how to reduce core damage. What's the most efficient way and the most appropriate way to reduce core damage frequency to an acceptable level? And we're making a transition now in how we think about that and I just need to hear more before I can make a comment.

CHAIRMAN RICCARDELLA: Okay. I'm just going to interrupt for a second. I think I heard the crackle. Is there anybody on the line that would like to make a comment?

MEMBER MARCH-LEUBA: Nobody phoned in on the line.

CHAIRMAN RICCARDELLA: Nobody?

MEMBER MARCH-LEUBA: Not that we hear.

CHAIRMAN RICCARDELLA: Okay. Okay. Jose, Mehdi, so thank you. That's it.

MEMBER CORRADINI: No comments. Thanks to Jose and Mehdi.

MEMBER SUNSERI: I find it to be an interesting advancement of the state of practice I guess in this particular area.

I suppose my overall feed, input similar to Harold here, is saying that, you know, I think we need to be cautious about how we go about utilizing and or applying those, because my experience is if you start tweaking with hardware to try to make analysts come out in different areas, it's tricky business. And you can cause unintended consequences to solve a problem.

(Off microphone comment.)

MEMBER SUNSERI: So that's the only

caution I offer at this time. I do appreciate the presentation. Thank you.

CHAIRMAN RICCARDELLA: Joy?

MEMBER REMPE: I don't have any additional comments but I do want to thank you for taking the time and coming and talking to us.

MEMBER MARCH-LEUBA: I want to also emphasize a thank you because that was a very interesting presentation. You see it was very lively and everybody wanted to hear about this.

My main concern when these things happen is whether it may be misused. I mean, whenever you give an applicant additional margin, he might come down the real safety of the plan by using additional margins. So that's a warning that let's make sure that this results in safer plants.

(Off microphone comment.)

CHAIRMAN RICCARDELLA: Okay. Thank you.

MEMBER BALLINGER: No more additional comments.

CHAIRMAN RICCARDELLA: Okay. Well, with that I'll thank you again and I guess we'll adjourn the meeting.

(Whereupon, the above-entitled matter went off the record at 2:54 p.m.)

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Correlations of Seismic Performance in Similar SSCs (Structures, Systems and Components) – NUREG/CR-7237

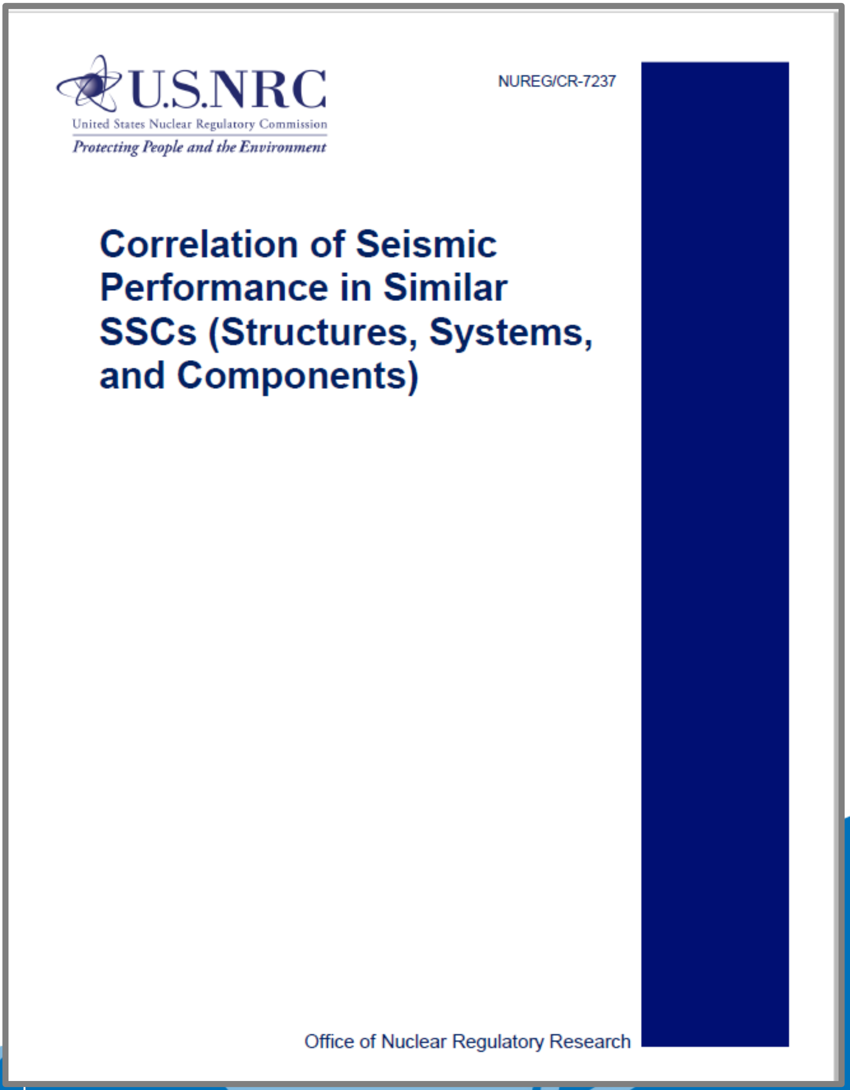
Information Briefing to:
Advisory Committee on Reactor Safeguards
Structural Analysis Subcommittee

October 3, 2018
Rockville, MD

Staff presenters/speakers:
Jose Pires, RES/DE
Mehdi Reis-Fard, NRR/DRA/APLB/RILIT
Selim Sancaktar, RES/DRA/PRAB

Overview

- Background
- Objectives and Goals
- Scope
- Analysis Aspects
- Study Approach
  - Review of Existing PRAs
  - Review of Current Literature
  - Workshops with Experts
- Analysis Process in a SPRA and Issues/Uncertainties
- Summary and Remarks
- Further Questions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NUREG/CR-7237

Correlation of Seismic Performance in Similar SSCs (Structures, Systems, and Components)

Office of Nuclear Regulatory Research

Background

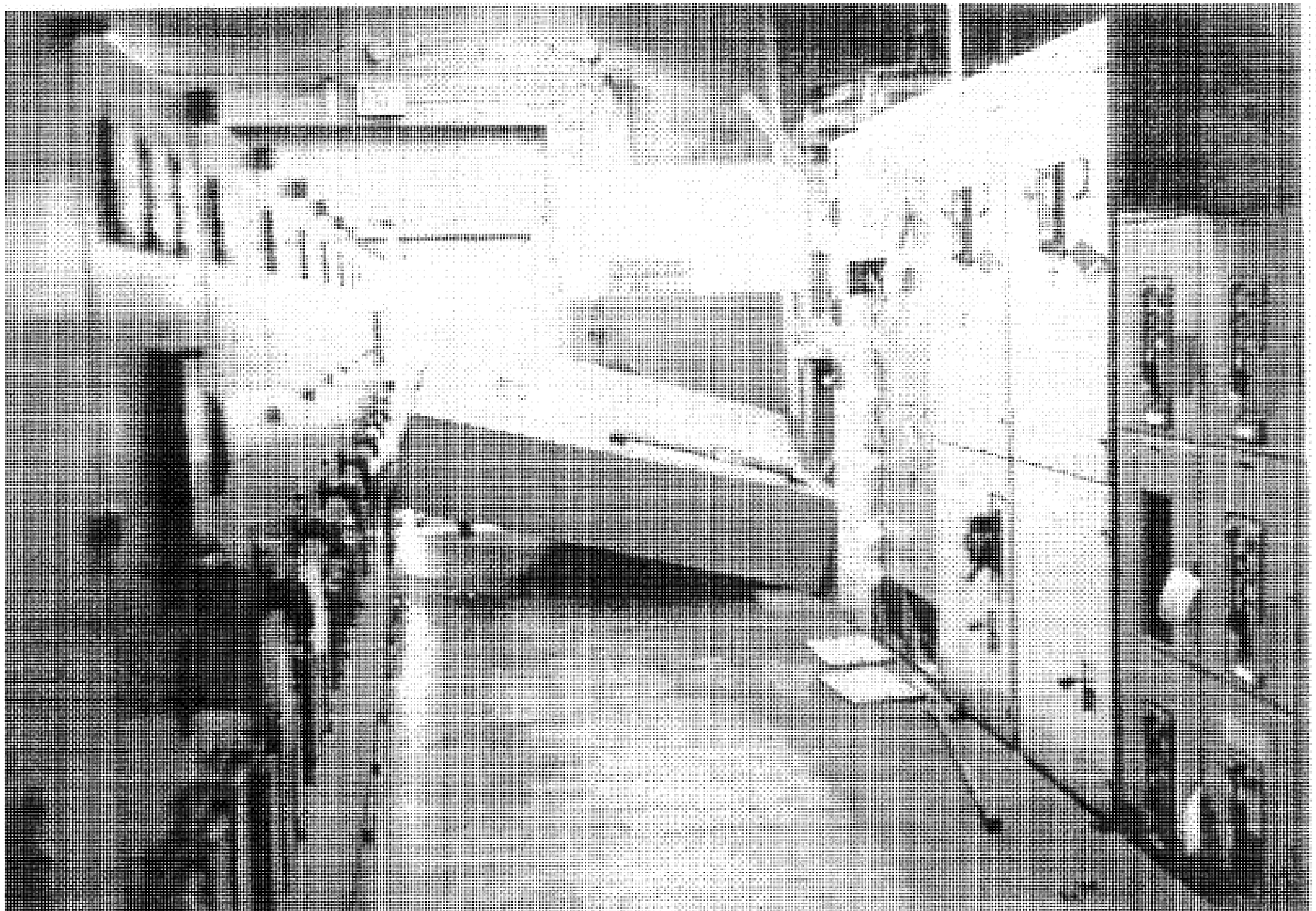
- Seismic Probabilistic Risk Assessments (SPRAs) have been conducted worldwide for over 35 years
- Two key SPRA aspects
  I. All possible earthquake levels, their frequencies of occurrence and potential consequential damage should be considered
  II. Earthquakes can simultaneously damage multiple redundant components
- Risk-quantification should account for this 'common cause' effect

Background

1994 Northridge earthquake

Haiti

Background



Single Motor Control Center Failure at Piti Power Plant – Guam (1993 Earthquake)

Background

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IMG_5952


IMG_5973

Fukushima Daini Make Up Tank Failures – Dependent Failures

Background

- Treatment of dependent failures involves a set of assumptions (rules-based approach) such as:
  - Similar redundant components next to each other and subjected to similar seismic forces fail simultaneously
  - Diverse or similar components at different (far apart) locations fail independently
  - Sensitivity analysis to postulated bounding assumptions
- This approach can mask insights and lead to varying degrees of conservatism in various places of the analysis

Background

- The treatment of dependencies of seismic failures in SPRAs depends on the intended use of their results.
- Further demonstrations of the identified methodology and its use would depend on arising uses or needs or, for example, applications to new designs, namely advanced non-light water reactors or modular reactor designs.

Objective

- As part of the 2010-2014 seismic and structural research plan, the Office of Nuclear Regulatory Research (RES) initiated research to:
  - evaluate and explore the seismic correlation-dependency topic and, if feasible,
  - to propose one or more advanced, more refined and more insightful analysis approaches for its treatment in seismic Probabilistic Risk Assessments (PRAs).

Goals

- That the evaluation of existing methodologies, the review of the related SSC-failure database, and the attributes of the proposed analysis methodology will inform SPRA analyses, peer-reviews, and staff reviews in relation to the treatment of seismic failures dependencies in seismic PRAs for operating and new reactors.
- Identification of a methodology that with further demonstrations (by its potential users) and use will provide an improved and more insightful approach to seismic PRA

Scope

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- Assessment of impact of correlation assumptions made in modern SPRAs have on risk estimates (concentrating on CDF)
- Review and identification of analysis methods and data sources that could be developed for improved and more insightful risk assessments
- Identification of a pathway (methodology) so that improved analysis of dependent seismic failures could become a standard part of SPRAs

Analysis Aspects

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- Dependencies arise in the system analysis part of a PRA
  – Dependencies of SSCs arise in the calculation of the failure frequency of a sub-system of SSSs with performance defined by a Boolean (logic) statement
- SSCs in parallel (redundant SSCs for example) involve 'AND gates'
  – Assumption of dependency results in an upper bound estimate of the sub-system failure frequency (system fragility)
- SSCs in series involve 'OR gates'
  – Assuming independency results in an upper bound of the sub-system failure frequency (system fragility)

Analysis Aspects

- Dependencies arise in the system analysis part of a PRA
  - Output of the analysis of the sub-system Boolean expression is essentially a fragility function for the system
  - Simplified (anticipated to be bounding) assumptions are typically made
  - An improved methodology would obtain narrower bounds on the system failure and address sensitivity of the results to defensible assumptions on dependencies and correlations
- Approach: involve fragility and system analysts to obtain fragility functions for the sub-systems functions (Boolean expression)

Analysis Aspects

- Seismic Fragility: $A = A_m E_R E_U$
  - A_m = median, E_R= inherent random uncertainty about the median and E_U = epistemic uncertainty about the median
- Usually A = F x RE
  - F = a factor of safety and RE = a reference 'size' of earthquake
- $F = F_C F_{RS} = (F_S F_u)(F_{SA} F_d F_M F_{MC} F_{EC} F_{SD} F_{SS})$

Capacity factor

Seismic response factor

Partial factors

Analysis Aspects

- Seismic Fragility: $A = A_m E_R E_U$
  – When there are several components in a Boolean statement, (B, C, D, …) the method involves:
    - Determining the correlation for the E_U uncertainty between components (co-variances)
    - Assigning the remaining uncertainty (independent part of the uncertainty) to each component (preserving the total uncertainty)
      – Similarly for the uncertainties for E_R
  – Then the methodology uses a set of rules to determine the frequency of the sub-system failure

Analysis Aspects

- Uncertainties
  1. Determination of the correlation coefficients for the uncertainties in E_U and E_R
  2. Subsequent set of rules to calculate the sub-system failure probability
- Item 1 – The correlation coefficients can be determined from the partial factors of safety and the combined to obtain those for E_u and E_R (may reduce variability among analysts)
- Item 2 – Verification of the simplified method against more rigorous existing mathematical approaches (too onerous for general use)

Study Approach

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- Review of several SPRAs in the literature (Chapter 4)
- Review of the existing literature on seismic correlation and dependency analysis (Chapters 2, 6 and 7)
- Review of existing data from testing and earthquake experience (Chapter 3)
- Identification of a possible improved and more insightful methodology for treating dependencies in a SPRA

Review of SPRAs

- Assessed impact of assumptions on the treatment of dependencies on the seismic failure of SSCs in risk estimates (concentrated on Core Damage Frequency (CDF) risk estimates)
- Almost all SPRAs used the rule-based approach with few exceptions
  - The Zion SPRA for the Seismic Safety Margins Research Program (SSMRP) and the Diablo Canyon SPRA
- Reviewed 10 SPRAs with CDF estimates ranging from 1E-7/year to 2xE-5/year

Review of SPRAs

- Observations from the review (examples), which used expert judgement:
  - For some SPRAs, the differences in the seismic CDF could range from close (but less than) a factor of 2, but with a typical difference in the range of 30% to 60%.
  - For some accident sequences, the differences could be larger (as much as factor of 2 to 4)
  - Treatment of dependent failures has small impact if the CDF is controlled by an accident sequence that is itself controlled by a single SSC (singleton).
  - For several SPRAs the CDF estimates are not very sensitive to the dependencies issue but risk insights can be sensitive to the assumptions made in the analysis of dependencies
  - A few types of SSCs seemed to appear repeatedly among those for which the assumptions used affected the results (the CDF estimates) (although not all affect the results in every SPRA reviewed)

Review of SPRAs

- SSCs that seem to appear repeatedly among those for which the approach to analyze dependencies in their seismic failure can affect the CDF estimates (not all appeared in this manner in all SPRAs reviewed):
  - Masonry walls
  - Electrical Motor Control Centers (MCCs)
  - Large tanks: condensate storage tanks of other similar tanks
  - Small tanks: diesel generator fuel oil day tanks
  - Heat exchangers: such as component cooling water heat exchangers
  - Mechanical: long-shafted service-water pumps, horizontal auxiliary feedwater pumps (motor and turbine driven dependency)
  - Batteries and racks

Review of Existing Literature on Dependency Analysis

- A variety of approaches with different level of mathematical rigor have been proposed
- SSMRP approach
  - Used join-lognormal distributions for the response and capacity of SSCs in a cut-set
  - Defines cut-set failure as all responses exceeding their capacities
  - Integrates the joint distributions over the failure region
  - Used in the Zion and SPRA and to derive a set of simplified rules (rule-based approach) called the Bohn-Lambright rules
  - Practice tends to use further simplified rules, which assign 100% to the situation of similar SSCs exposed to the same earthquake load (typically, SSCs located near each other), and zero everywhere else.

Review of Existing Literature on Dependency Analysis

- Bohn rule-based approach

Rule #	Description
1	Components on the same floor slab and sensitive to the same spectral frequency range (i.e., ZPA, 5-10 Hz. or 10-15 Hz) will be assigned response correlation = 1.0.
2	Components on the same floor slab sensitive to different ranges of spectral acceleration will be assigned response correlation = 0.5.
3	Components on different floor slabs (but in the same building) and sensitive to the same spectral frequency range (ZPA, 5-10 Hz or 10-15 Hz) will be assigned response correlation = 0.75.
4	Components on the ground surface (outside tanks, etc.) shall be treated as if they were on the grade floor of an adjacent building
5	"Ganged" valve configurations (either parallel or series) will have response correlation = 1.0.
6	All other configurations will have response correlation equal to zero.

Review of Existing Literature on Dependency Analysis

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- The review identified an approach that would lead to a more refined and more insightful methodology
  - Initially proposed by Reed and McCann (1985) but not further developed
  - Leverages approaches widely used in the fragility analysis of SSCs that lead themselves to engineering identification of correlations in the uncertainties of variables that determine and SSC fragility estimation

Review of Existing Data

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- Main observations in relation to data-driven support for determining seismic failure dependencies
- Shake-table testing data
  - Shake-table test data is largely inadequate for purpose of understanding dependencies among failures – Mostly qualification testing data and when taken to failure mostly testing of single items
- Earthquake experience data
  - Largely inadequate for the purposes of understanding the dependencies among seismic failures – Sparse data, difficult to understand and large interpretation uncertainties

Analysis Process in a SPRA

1. Performance of a SPRA using standard methods

Needs to include sufficient sensitivity analysis studies)

2. Identification of those (presumably few) cut-sets or accident sequences where correlations analysis 'makes a difference'

Difference in terms of risk quantification, importance, and safety insights

3. Use the improved methodology to study the identified cut sets or accident sequences one-by-one.

<u>Revised fragility functions</u>

4. Use of the revised fragility functions in the SPRA in the usual way

May involve iterations to Step 3 or Step 2

Analysis Issues/Uncertainties

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- Difficult to use methodology for the 'revised fragilities' except for most experienced SPRA fragility analysts
- Variability among fragility analysts
  - Variability from analyst to analyst
  - Expert judgement to assign uncertainties as dependent or independent (determining coefficients of correlation)
  - Would need further sensitivity assessments
- Issue of data availability and focus on matters of more or less conservative analyses (instead of, for example, looking for safety insights)
- Peer-review needs

Summary / Remarks

- As part of the 2011-2014 seismic and structural research plan RES initiated research to explore the topic of dependent seismic failures of SSCs is SPRAs and, if feasible, to identify more refined and insightful analysis approaches for its treatment in SPRAs.
- The research documented reviewed past SPRAs, the SSC-failure database, and identified a more refined and insightful methodology that has promise for practical treatment of the dependency issue in SPRAs
- The methodology described needs further demonstrations (by potential users) to provide an new and more insightful approach for SPRAs (in relation to the treatment of dependency of seismic failures)

Summary / Remarks

- The treatment of dependencies of seismic failures in SPRAs depends on the intended use of their results.
- Further demonstrations of the identified methodology and its use would depend on arising uses or needs or, for example, applications to new designs, namely advanced non-light water reactors or modular reactor designs.