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

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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SUBCOMMITTEE ON SITING

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TUESDAY

NOVEMBER 30, 2010

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ROCKVILLE, MARYLAND

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 2:30 p.m., Dana A. Powers, Chairman, presiding.

SUBCOMMITTEE MEMBERS:

DANA A. POWERS, Chairman

MICHAEL T. RYAN, Member

DESIGNATED FEDERAL OFFICIAL:

DEREK WIDMAYER

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

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

2:29 p.m.

CHAIRMAN POWERS: We will now come to order.

This is a meeting of the Advisory Committee on Reactor Safeguards Subcommittee on Siting. I'm Dana Powers, Chairman of the Subcommittee.

ACRS members in attendance are Michael Ryan. Derek Widmayer of the ACRS staff is the Designated Federal Official for this meeting.

The purpose of the meeting is to hear the status of resolution of Generic Safety Issue 199, Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants.

This is an information briefing. The Subcommittee will hear presentations by and hold discussions with the NRC staff and other interested persons regarding these matters. The Subcommittee will gather relevant information today on resolution of GI-199 and future actions planned by the staff and take the matter of future deliberations on this issue under advisement. The matter is not scheduled for full Committee meeting at this time, and no letter report is planned. However, I think the staff is very much interested in background, and I suspect that I will do a summary description of this meeting before the full Committee during probably our Planning and Procedures Subcommittee because it's a relatively significant issue to discuss with them.

MEMBER RYAN: This week.

CHAIRMAN POWERS: This week, yes.

Rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the *Federal Register*. We have received no requests for members of the public to speak at 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 microphones located throughout the meeting room when addressing the Subcommittee. The participants should first identify themselves and speak with sufficient clarity and volume so they may be readily heard.

Copies of the meeting agenda and handouts are available in the back of the meeting room.

A telephone bridgeline has been established with the meeting room today. And I understand we have participants on the line for the meeting. We request that participants on the bridgeline identify themselves if they speak and to keep their telephone on mute during times when they're just listening.

MEMBER RYAN: Do you want to take the roll on the phone?

CHAIRMAN POWERS: I see no reason.

MEMBER RYAN: All right.

CHAIRMAN POWERS: Do you have any opening comments you want to make?

MEMBER RYAN: No, sir. Thank you.

CHAIRMAN POWERS: Okay. I'll now turn to John Kauffman of the Office of Research for some introductory remarks.

MR. KAUFFMAN: Thank you, Dana. Actually Lauren Killian is going to be doing the introduction.

CHAIRMAN POWERS: Lauren's got the tough job of keeping this wild crew in line.

MS. KILLIAN: Yes, yes.

CHAIRMAN POWERS: Okay, Lauren. It's up to you, but we have a ground rule here in these Subcommittee meetings. You can't talk unless you tell us a little bit about your background so that we know something about who you are.

MS. KILLIAN: Okay.

CHAIRMAN POWERS: Okay?

MS. KILLIAN: Good. Well, I'm Lauren Killian. I am in the Office of Research. And I've been a project manager -- one of the project managers on Generic Issue 199.

CHAIRMAN POWERS: What? Now where did you go to school? What's your background? What did you do before you came to the NRC?

MS. KILLIAN: Well, before I came to NRC, I went to MIT. I was there for mechanical engineering, and I got my Bachelor's and Master's.

CHAIRMAN POWERS: Okay. We won't hold being from MIT against you.

(LAUGHTER.)

CHAIRMAN POWERS: But it does put additional burden on you.

(LAUGHTER.)

CHAIRMAN POWERS: Go ahead.

MS. KILLIAN: All right. Well, thank you.

All right. As you said, we're talking about -- going to give you a status update on Generic Issue 199.

Let's see. This is our agenda. First, I'll give a background on the Generic Issues Program and just to give context for Generic Issue 199. And then John Ake and Marty Stutzke will talk for the main body of the presentation. And they'll be talking on the safety risk assessment.

I think you probably know --

CHAIRMAN POWERS: This is going to be interesting to listen to a background. You know the Generic Issues Program is an invention of the ACRS, right?

MS. KILLIAN: Quite a long time ago. Yes.

(LAUGHTER.)

MS. KILLIAN: Okay. Great.

Let's see. I guess just for quick introductions for them, John and Marty were both the others of the safety risk assessment report. And then John is a senior seismologist, and Marty is the senior technical advisor for Probabilistic --

CHAIRMAN POWERS: Those two guys we know.

MS. KILLIAN: In case anyone else.

(LAUGHTER.)

MS. KILLIAN: Okay. Pat Hiland will give the path forward. And he has been the chairman for both the screening and the safety risk assessment panels for Generic Issue 199. And then for anyone else, he's the director of the Division of Engineering for NRR.

Then at the conclusion, I guess there'll be more room for discussion.

All right. To start the overview, the Generic Issues Program -- as you probably already know -- but it's an Agency-wide program. It's managed by the Office of Research. And out of the operating experience and generic issues branch. And that's how I'm involved.

The program is mandated by Congress, and it's been updated over time. But as you know, it's been around for over 30 years. So --

CHAIRMAN POWERS: Since the dawn of time.

MS. KILLIAN: Yes. The Generic Issues Program is designed to address safety and security issues affecting more than one facility that do not have a clear home in a current like regular regulatory process. And that's either because they might be outside of the current regulatory framework or technical significance of the current concern is unclear at that point.

So here are the Generic Issues Program stages. The first one identification, and in the case of Generic Issue 199, that was identified by NRR.

The second stage is acceptance. And this consists of just a pretty modest effort -- pretty small -- in the Generic Issues Program we increase effort as we work through an issue. So acceptance is fairly small.

And then we go on to screening which is more preliminary analysis. And there we compare it against seven criteria that we have for the program. That's new in the last several years. And we see if they can either address it in already existing programs or if it should be addressed in the Generic Issues Program.

If we determine it is a form of generic issue, then we will write a communication plan for it. It can be the screening panel, work on consensus and come up with the plan to go forward and then hold the public meting at the end of the screening stage.

CHAIRMAN POWERS: Do you happen know how many generic issues are being pursued by GIP?

MS. KILLIAN: As far as numbers-wise --

MR. KAUFFMAN: There are five that either open in the program or open in reg office implementation.

CHAIRMAN POWERS: What I'm just thinking, John, it's been quite a while since the ACRS has had a briefing on the Generic Issues Program, and an awful lot of new members that have never seen a briefing on the Program. Maybe it's something we ought to chat about whether it's worthwhile to have just an information briefing on it.

MR. KAUFFMAN: Sure, we can do that.

CHAIRMAN POWERS: I mean, I wouldn't make a big deal about it. But I'm thinking that there are -- I mean, how many -- Shack and Sieber and I have certainly had briefings on it. But I don't know --

MEMBER RYAN: I would say more than half have not.

CHAIRMAN POWERS: Yes. More than half have not. And I'm wondering if it wouldn't be worthwhile to have a briefing that just said okay, here's the issues we're pursuing, how the thing becomes an issue, here's how it goes through the winnowing process strictly for information.

MEMBER RYAN: Yes, that would be a good idea. I'd second that.

MR. KAUFFMAN: I think that makes sense. There was a major overhaul of the program initiated with some Commission direction, led to SECY-07022.

CHAIRMAN POWERS: Right.

MR. KAUFFMAN: And last year, the MD6.4 was revised. So there have been a lot of changes in the last few years.

CHAIRMAN POWERS: Yes. And it's been a long time. So maybe just put it down in our tickler file to chat with him. Getting on the agenda is kind of chore nowadays, and this is a luxury. So it's when our mutual schedules permit doing it because I mean it really is an indulgence, but it sounds like a worthwhile indulgence to me.

MEMBER RYAN: It would be helpful to just add -- you mentioned several documents as you were talking -- a bibliography of kind of take-home reading to get folks up to date would be helpful too.

MR. KAUFFMAN: And just as an aside, we did have an RES seminar I want to say in 2008 going over the changes to the program. And we have those available. You could just use those viewgraphs and -- I mean, I'm saying not knock yourself out on something special.

MEMBER RYAN: Yes.

MR. KAUFFMAN: Just an information. Maybe just make a tickler file on that.

CHAIRMAN POWERS: You're the man that knows all about this stuff, and also knows how it's easy for members to get -- welcome, sir.

PARTICIPANT: Thank you.

CHAIRMAN POWERS: Sorry, Lauren.

MS. KILLIAN: All right. I think we just finished talking about stage 3 which is screening.

So going onto stage 4 which is the safety risk assessment. And that's really why we're here. So we're focusing on that one for the rest of the presentation.

Let's see. Just as a brief overview, as part of the safety assessment stage, we analyze the issue in more depth than the previous stage. And then the analysis was reviewed with the safety risk assessment panel that Pat chaired with experts from around the Agency. Then we worked to kind of gain consensus on the path forward. And we wrote a report. That was issued. And then the recommendations were all agreed upon between the Office of Research, NRR and Office of New Reactors. And we had a public meeting as we were finishing up with that.

And for GI-199, the safety risk assessment stage at the end of that, that's when GI-199 actually exited the Generic Issues Program. And we'll talk a little bit more about that in a moment.

So if it had gone onto the next stage, the next stage would have been regulatory assessment. That's the final stage and basically where you look at options and consider those and identify which is the best one and see if you can impose it within the constraints of the program.

So that should do it for the stages.

CHAIRMAN POWERS: Now an ITAAC.

(LAUGHTER.)

MS. KILLIAN: It's okay that you can't read the --

CHAIRMAN POWERS: Why is it okay that we can't read the details --

MS. KILLIAN: Think of it in terms of columns. So if you see if kind of as three columns, then that's good enough on this one.

Basically what this is getting at is they're trying to put the General Issues Program in perspective with the other regulatory programs if possible. So if you think of the middle column as being the General Issues Program, you kind of work from the top where you have a proposed issue. And then as you work down that column, that's working kind of of through kind of the steps we were talking about roughly.

Let's see. Just as you work down through the General Issues Program, we develop knowledge on the issue until we determine that either it's not safety and it can leave the program altogether. Or if it's understood sufficiently, it can be handed over to the address by existing regulatory programs and processes.

So it can leave the General Issues Program at any time, and it can either go off that left column which represents long-term research and scoping studies. Or it can go off to the right column which is other existing initiatives and activities.

And for GI-199, we found that it's sufficiently significant to continue to be addressed. And that's kind of according to the General Issues Program risk matrix that we have. We'll talk about it a tiny bit more.

But it can't proceed directly to the regulatory assessment stage that we were talking about because more information is needed. So that's why it's exited the program that I mentioned before. So it's gone from the middle column off to the right column now because it's been transferred to NRR. And they have processes in place where they kind of will facilitate in obtaining that information and it'll be continued.

CHAIRMAN POWERS: When I looked at this slide, the one thing that stands out to me is that if you send it on to long-term research, it never comes back.

MS. KILLIAN: Yes, it could. If you want to pipe in on this.

MR. KAUFFMAN: Yes. There is --

CHAIRMAN POWERS: I mean it sounds like a great way to bury an issue. Put it in long-term research, it never emerges again.

MR. KAUFFMAN: Well, the idea is the General Issues Program should deal with generic issues. It's not a program to manage research activities, that Research is the appropriate organization to manage it.

And it's meant to address some of the criticisms that old generic issues were studied forever and if they were that important, what were we doing with them.

CHAIRMAN POWERS: And 191 being --

MR. KAUFFMAN: It's certainly one thing the program does do is when we get an issue, if it didn't originate in the program office, we inform the program office about the issue so that they can determine if there's need for any immediate actions.

CHAIRMAN POWERS: Okay.

MR. COE: If I could add just one thing.

This is Doug Coe with the Division of Risk Analysis, Office of Research.

The last block on that left column is actually a transfer block that would either take the issue back to the regulatory office or to be re-submitted as a proposed generic issue and then go through the process.

So really the re-design of the General Issues Program over the last few years has been designed so that we do avoid what the Committee most properly pointed out in the mid-1990s that issues were resident in the program for far too long. And I think the changes that have been recently fully implemented now are serving to avoid that.

CHAIRMAN POWERS: I don't know that we need to get into a big discussion here, but one of the things that I would worry about is it's not clear to me how you sustain a long-term research over there without some support from NRR or NRO or NMSS. And it's not evident in the block diagram there.

MR. COE: Right.

CHAIRMAN POWERS: Go ahead.

MS. KILLIAN: That pretty much concludes my part giving an overview of the General Issues Program. Unless there's any other questions, then --

MEMBER RYAN: Just one follow up. Have you tracked the change in the time that the issue has been resident? Has there been a measurable improvement? Or is that --

MR. COE: That's a good question. I don't know. John, can you --

MR. KAUFFMAN: We have some graphs and statistics on that. And we recently briefed the Chairman on that. I did not bring those today.

MR. COE: But we can make those available to you.

MEMBER RYAN: Okay. Thanks.

MS. KILLIAN: All right. With that, if John would like to start talking about the safety risk assessments.

CHAIRMAN POWERS: Sure.

MR. AKE: Go ahead and hit the next slide, please.

Well, what I'd like to do is take a few minutes and walk you through a few slides that provide a little bit of technical and regulatory background for this particular generic issue, and a little bit about how it came to be. And then with that, I'll begin to step through the technical approach focusing mostly on the seismic hazard portion of it, and then

I'll turn it over to Marty where he'll provide some clarity after I make everything confusing as he always does.

This particular plot that we show on this slide illustrates a couple of points. First of all, let me reiterate that the title of this particular generic issue is Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants. Key elements here are existing plants. So this has no real direct relationship to those licenses that are under or applications rather that are under review. The COLs and ESPs, they're currently being reviewed by NRO.

And by what we mean in this context for the central and eastern United States is approximately east of 104 degrees, about the longitude of Denver approximately and eastward.

This plot shows something else. It plots felt and damaging earthquakes in the United States from the USGS as well as current operating power plant locations, and illustrates first that it's a good news/bad news. The good news is that the majority of earthquake activity is west of that boundary which is good news. Unfortunately, the majority of the power plants are east of that boundary and fall within the purview of this generic issue.

We evaluated 96 separate plants as part of this issue. And Marty will touch on why we ended up having to actually look at all 96 as opposed to taking a more generic approach to this.

Next slide, please.

The safety and risk assessment as Lauren pointed out is currently what we're going to describe is the safety risk assessment portion of this project. And it had two goals as we show on this slide here. And Lauren walked you through those already. And Pat will summarize the summarize the second bullet for us in a moment.

Go to the next one.

This is a plot that I guess I look to you a little bit for guidance here, Dana. I'm not going to explain quite as much on this on some of these slides as I normally would because of the background of the Subcommittee members.

CHAIRMAN POWERS: Quite frankly, the slide's totally self-evident to me.

MR. AKE: Yes.

CHAIRMAN POWERS: And --

MR. AKE: I'm assuming everybody is quite familiar with hazard curves and what they tell us and what they show us. Okay.

MEMBER RYAN: I sat with Bill Heinz for four years. I'm good.

MR. AKE: Good. Okay. Thank you. Because I'll probably gloss over some of these. But please stop me if you want me to go into more detail on it, please.

But this illustrates the observations that we noted in comparing results from the results that we calculated using a relatively recent seismic hazard model for the eastern U.S. from the United States Geological Survey compared to the 1980s and early '90 vintage hazard results.

And as you can see from this plot, even though these results are in general agreement at the safe shutdown earthquake or SSE level, as you go to higher and higher accelerations or lower annual exceedance frequencies, there is a difference between the older results and the newer results. And that was really the genesis part.

I'll make another notation about this in a moment with a different context. But that was really the genesis of this particular generic issue.

CHAIRMAN POWERS: One of the points that I'll start making right now, but I'm going to hit you with this a lot, is certainly with the current Commission, we make this point. Dr. Apostolakis is going to say no -- not true. But if in fact I take into account I'm certainly in those curves out there, there's no more difference out at the .7g acceleration than there is at the .2g acceleration if I didn't take into account uncertainty in the curves.

MR. AKE: The curves that we are plotting here do have uncertainty in them -- I should say implicitly or explicitly -- explicitly because these are the mean curves.

CHAIRMAN POWERS: Right. And so if I put the variance on that mean around there, you cannot find a statistical difference -- I mean, equal difference between those two points out there.

MR. AKE: The question -- I'm going to try and re-state your question to make sure I understand it.

If I was to do a test of the mean, is the mean at say .6g, is the mean annual exceedance frequency different for the USGS --

CHAIRMAN POWERS: Yes.

MR. AKE: -- 2008 versus -- is there statistical significance to the means?

I suspect out there, but at 10^{-5}, I'll wager there probably still is a statistical significance.

By the time we get down to lower annual exceedance frequencies, I'm not so sure that I would lay claim to that.

CHAIRMAN POWERS: And that's good. And that's the thing that's going to be a hang up I think in taking this forward to the Commission. They're just going to get hung up on this uncertainty business, primarily parametric uncertainty with Apostolakis. I mean, he wrote the book on model uncertainty. And complete in the sense I think is beyond the pale.

But I think you're going to have to worry about that especially taking it forward to the Commission level just because of the personalities and what not. You're going to have problems with that even with the ACRS. Okay?

I said my -- but I'll say it again several times as we go through the presentation I'm sure.

MR. AKE: Okay. So that was really the genesis that led to this particular generic issue being proposed, although it wasn't exactly in this form. But there was a notation of that or noting those particular observations is what led the staff and NRR at the time to submit this as a generic issue.

I'm sure you probably all know what a response spectrum is. It's widely used in our engineering and it's really a way that we're going to be showing many things throughout this. As you well know, it's just a peak response of a series of similar degree layers of different natural frequency constant damping -- the peak values of each of those plotted. Connect the dots and that's the response spectrum.

But it's to a constant input. And that's what we illustrate at the bottom. If we're feed that accelergram into that series of oscillators represented mathematically and plot the peak results, that the response spectrum.

I also point out on this slide that you'll hear us the way we're particularly expressing seismic hazard amplitudes if you will in this study for the most part is in acceleration and g. That's pretty much the common standard in the United States. So I hopefully stuck to g everywhere. Obviously because of the fact that we have structure systems and components -- there are safety significance that have different natural frequencies, we of course have to find a way to represent and consider those different natural frequencies in our results.

All of the plants that we examined here were licensed prior to 1997. And so the appropriate regulations are contained in 10 CFR Part 100.1 in Appendix A. That establishes the seismic design bases for the plants.

The language in those regulations I should say -- in blue here -- is based on a review of earthquakes that have occurred near the site. And it's a deterministic approach. And I point this out because it's quite different than what we are currently doing post-1997, and that's there no specification of frequency of occurrence associated with this. It is a true deterministic assessment.

In Appendix A under general design criteria requires that the SSEs -- the language specifically says "be designed to withstand the effects of natural phenomena without loss of capability to perform their intended safety functions."

And also, appropriate language that we'll come back to a little bit is the appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area -- and I'll touch on that in another slide in a moment -- and that the assessment includes sufficient margin to account for the limited accuracy, quantity and creative time in which the historical data have been accumulated.

Obviously in the United States, we don't have a particularly long historical record to rely upon to develop some of these things, especially vis a vis instrumental recordings -- very short period of time. And in places like the central and eastern United States where the activity rate is low, Mother Nature doesn't give us much information on a very regular basis. So --

MEMBER RYAN: John, I recall at the South Carolina plant discussion where they had started to strip off some top soil and so forth, the lack of evidence was as meaningful as evidence of an earthquake. So are you going to touch on that at all -- or maybe not? But --

MR. AKE: Not really in this, I'm afraid I'm not actually.

MEMBER RYAN: That's fine. I'm right in reading that the absence of information of any previous earthquake is as important in some evaluations as the evidence of an earthquake and what it might have been, or am I off base there?

MR. AKE: It's important but we have noted this in our evaluation of trying to look historically or paleoliquefaction -- prehistoric rather or paleoliquefaction. In and of itself it is not --

MEMBER RYAN: Not determinative?

MR. AKE: It's not determinative that it -- positive evidence is very useful. Negative evidence is useful but it looks somewhat less utility because it's difficult to say it couldn't possibly --

MEMBER RYAN: Okay. That's just what I was looking for is the balance between the two.

MR. AKE: Right.

MEMBER RYAN: Thank you.

MR. AKE: Yes. And so the last thing I wanted to point -- and this is somewhat important to say -- is that there currently is no requirement for a periodic reassessment of the seismic design basis. So once this is set, it is set. And that is a meaningful thing that we'll touch on a little bit later.

Go onto the next one, Lauren. That's fine.

I'd like to just briefly walk through how that language is actually used in the development of the safe shutdown earthquake or SSE.

In Appendix A, the SSE is defined as "that earthquake that provides the maximum vibratory acceleration at the site." And the way that the language on the previous slide was actually used that based on a review of earthquakes that have occurred near the site and appropriate consideration of the most severe of the natural phenomena that has been historically reported in the surrounding area was the following. If we take an example site there in the middle of our bull's eye there and recognize that we perhaps may or may not have fault structures indicated by the dark lines, we would assess those for the likelihood of producing earthquakes -- there's seismogenic potential -- unfortunately in the eastern United States, we generally do not have surface faults we've been able to identify and characterize as producing earthquakes.

So the next order of business then is to evaluate the occurrence of earthquakes within geologically or tectonically similar terrains to the site itself and evaluate the earthquakes -- the maximum-sized earthquakes that have occurred in each one of those areas. And the way this was done for the currently licensed plants is when the epicenter of the largest event could not be related to a specific tectonic structure, it was assumed to occur at the closest location to the site -- to our proposed site.

And so there was clearly some degree of conservatism that's probably added to this process by this transposition of earthquakes from one location to another in developing the SSE.

Now once those earthquakes have all been defined and their locations established, either what are called empirical ground motion prediction equations or attenuation relationships are used to determine the site acceleration that results from earthquakes of that given magnitude or that given observed macroseismic intensity -- modified Mercalli intensity or some other measure. Those are converted to a site acceleration.

Then both site accelerations are used to anchor a spectral shape. In this case, it's a response spectral shape as we described in the earlier slide. And this is the safe shutdown earthquake. And that SSE is anchored to that acceleration value -- the so-called peak ground acceleration. Typically historically was defined to be 33 Hz for most of these assessments. And this standardized response spectral shape was developed by evaluating a series of observed earthquake recordings in the early '70s for the most part were the earthquakes that were used to formulate this response spectral shape.

And that assessment looked at for each individual frequency the 84^{th} percentile of those observations for the earthquakes that were recorded. And that resulting spectral shape is what was used for most of the SSEs. There are two or three different --

CHAIRMAN POWERS: Thirty-fourth percentile because it's two sigma or something like that?

MR. AKE: One sigma.

CHAIRMAN POWERS: One sigma.

MR. AKE: Medium plus one sigma.

CHAIRMAN POWERS: Yes. One sigma?

MR. AKE: Yes. And there's two points I want to make about that. One, there's probably some conservatism because they're using -- some conservatism -- medium plus one standard deviation. Secondly, each of those individual response spectra for earthquakes suite that they looked at has a particular scallop shape. They treated each individual spectral frequency as a suite of observations and computed the 84^{th} percentile for each one individually. So in effect you're getting some enveloping going into the process there.

So I guess the other two key points I wanted to make, so the SSE derived in this fashion really contains no information about how often. It's a true deterministic assessment, and it's really not something we can easily import and use into any sort of PRA process for that reason.

Secondly, the SSE is unique to each individual plant now based on this process and the vintage of when it was developed. And in fact in some cases when you see co-located plants, the SSEs are different.

CHAIRMAN POWERS: Different.

MR. AKE: Simply because of the time frame --

CHAIRMAN POWERS: I certainly know of an incident associated with a plant that never got built where based on this analysis, the safe shutdown earthquake by this analysis would have been .1g. And applicant took it to the staff. The staff says we don't like that. So he said well, since I haven't built the plant, I'll make it .3g. Because it cost him nothing --

MR. AKE: Yes.

CHAIRMAN POWERS: -- since he hadn't poured any concrete yet.

I mean, there's a checkered history on these things.

MR. AKE: I would merely state that

reading the FSARs -- this section of all of the FSARs which I did as part of this -- was very interesting reading.

CHAIRMAN POWERS: Yes.

MR. AKE: Next one, please.

Quickly, the reason I'm going to talk very briefly about the applicable regulations post-1997 is because we're going to perform an evaluation -- I'll describe in a few moments -- that relies on evaluating what we would do today if we were to use this approach at a given existing reactor site. And the 1997 10 CFR 50 and 100.23 were developed. Appendix S was now the appropriate regulation that describes the seismic design basis for these plants. And the safe shutdown earthquake definition is basically the same as previously. The 100.23 contains slightly different language though. It requires the applicant to determine the SSE and its associated uncertainty. The potential for surface deformation was also specifically called out in that portion of the regulations.

Currently Regulatory Guide 1.208 provides the guidance for satisfying 100.23. And the method for satisfying 100.23 that's pointed out in 1.208 is performa probabilistic seismic hazard assessment or

PSHA.

Now the figure of merit to start with is something called the GMRS or ground motion response spectrum. And that's the first step in providing the SSE that's done under 1.208. And this now specifies specific target frequencies of exceedance for their link to desired performance goals for the new reactors.

And I guess that's probably it on that whole thing.

Very quickly, because you both are familiar with this, the difference in the probabilistic seismic hazard assessment versus deterministic, in the upper left is essentially the same general activities are conducted in terms of characterizing the seismic sources that were previously conducted for doing a deterministic assessment with the difference now being that those specific seismic sources -- again faults -- we show faults on that figure. Unfortunately that's not anything -- or fortunately I guess -- something we've been able to identify near any of the reactor sites in the east currently.

We have to define how large the maximum earthquakes are associated with all these sources, but now we also need to specify how often earthquakes of different magnitudes occur. And that all gets rolled up along with the empirical ground motion prediction equations to produce our hazard curves we saw an example of a few moments ago.

You guys are quite familiar with all this. So if you have any questions --

CHAIRMAN POWERS: Just ask one question. I'm just curious.

The annual number of earthquake plot versus magnitude, I think you're trying to depict some sort of a log normal relationship there.

MR. AKE: It is a truncated exponential distribution is the --

CHAIRMAN POWERS: Is there a reason for doing that? Or is that just a convenience?

MR. AKE: The portion of the curve that we plot there as a solid line, if one looks at earthquake occurrences in any reasonable-sized area where you have a large enough sample to really think you're getting a reasonable sample, it tends to plot exactly like that. The log of the number of events is equal to some intercept value A with a negative slope. So the B term there is the slope times the magnitude. And that's called the Gutenberg-Richter relationship.

And it seems to be ubiquitous if you look at a large area. Individual faults, sometimes yes, sometimes no.

CHAIRMAN POWERS: I mean, t his is almost a discussion we should have to the side. But when you look at the theory of what normal kinds of things, you find that kind of everything fits a log normal.

MR. AKE: If you take the log enough times, yes.

CHAIRMAN POWERS: And that if you look in detail that what it requires to actually be at log normal relationships that in fact the scatter that you usually skew is when you're trying to find a distribution that's not acceptable because of small difference. And I've often wondered if we did this probabilistic seismic hazard and took all of our log normal distributions and instead made them Levy distributions which are much heavier, would we get radical differences or not. And I don't know the answer to that. And I don't know that anybody has done it because this is log normal business. Engineers love log normal. I mean, once you figure them out, then you're going to use them. And you guys think that is so painful to figure them out.

MR. AKE: Well, your point is actually a good one, Dana, in the sense that -- this is an empirical observation -- it appears to hold.

CHAIRMAN POWERS: Yes.

MR. AKE: However, there are some subtleties with that.

If typically when we're doing probabilistic seismic hazard evaluations, the way I describe it, it's very painful. One gathers the catalog of all the possible earthquakes in the area, tries to make sure you have uniform magnitude scale so you're plotting apples and apples and everything and do all this. And so you end up with 10,000 earthquakes or something like that.

The assumption is that we're doing this assessment for independent events. That means you have to correct them. Many of those earthquakes that are in the catalog are foreshock, mainshock, aftershock sequences.

CHAIRMAN POWERS: Right.

MR. AKE: So you have to go through the painful process of identifying those dependent event sequences and removing the dependent events leaving only the independent of mainshocks. So you get 10,000 events and work your rear off trying to get all that and you throw 94 percent of them away at the end and end up with a small data set. That actually is what one is forced to do in this procedure.

However, there is interesting debate in the literature about what sort of distribution to actually apply to those mainshocks versus the entire population. Is it in fact still the -- where should alternative distributions be explored? I would only say that it's an active area of discussion.

CHAIRMAN POWERS: Yes. And in fact, I mean, it's one of those areas that Lauren would send over to her long-term research area and call them because I don't think we have the answer. But I think we have a tendency to look at these kill distributions too quickly, and especially on episodic events like this, we think our kill distributions seem like they're more logical. And we only get in trouble because we like to use semi-infinite distributions instead of truncated them off and things like that.

MR. AKE: And that's the difficulty is developing a technical rationale for the truncation of those.

CHAIRMAN POWERS: Truncation. That's right.

MR. AKE: You know physically the distributions. We see this in the ground motion space very strongly. The distributions are not infinite.

The strength of the materials prevents them infinite acceleration and things like that. So the question now is developing a defensible technical basis for how to do the truncation.

CHAIRMAN POWERS: And in San Andrea and things, they tend to use potential energy for truncation and things like that.

But of course on the east coast since we don't know the seismic structure, we can't do that.

MR. AKE: It's a challenging problem. It is one that I would mention. It is one we've been following and try to -- DOE was supporting a fair amount of research in this on that topic up until the cancellation of the Yucca Mountain project. And we have been involved in some of those studies and staying abreast of it. I don't know what the future of those will be now that DOE is pulling the money out of that.

CHAIRMAN POWERS: None of us know. And you're right. That was a source of a lot of what I would call the long-term research or detailed research that we could make use of.

MR. AKE: Yes.

CHAIRMAN POWERS: Okay. That was an aside.

MR. AKE: Yes. And of course, I would also note there that -- that's okay -- that because of the fact that we need to have this represent a suite of frequencies that's representative of the frequencies of vibration we might be interested in for our facilities. Yes, we will perform this assessment and develop hazards for several different vibrational frequencies.

And I'll do my best not to confuse this. Annual frequency of exceedance versus vibrational frequencies -- I'll try and be as specific. But wag your finger at me if I'm not --

CHAIRMAN POWERS: Don't worry. I get confused. There's too many frequencies around here.

MR. AKE: Yes. So the next slide I wanted to mention is this one here. It would be really nice if all the nuclear power plants that we were interested in were built on the same geological materials, specifically if they were on nice hard rock. Unfortunately that's not the case.

And what we know here is that the type and thickness of the materials that are near the ground surface have a very strong influence on the strength of the ground shaking and the duration of the ground shaking that's observed at a particular location.

This slide shows an example from recordings from a relatively small aftershock to the 1989 Loma Prieta earthquake that were recorded in downtown Santa Cruz, California. And it's a role of seismometers across a small alluvial basin. And the plot of these -- the Y axis on the plot at the bottom is time, and the X axis is amplitude of ground vibration. And you can see as we move from hard rock on the very left side of this profile out over the basin that the amplitude of the strength of shaking goes up by in this case something like a factor of five. And also note that the duration of shaking is significantly longer as well.

CHAIRMAN POWERS: That is ultra cool. I love it. That is really nice.

MR. AKE: We've seen this over and over and over again. And failure to take this into account will lead to potentially some inappropriate conclusions.

There's something that we have tried to take into account. And I'll describe briefly how we do this in a moment. But we used what I call the generic approach to estimating the site-specific amplification functions. For the current round of COLs and ESPs that are being reviewed by NRO, they make very specific objectives or -- what's the term I'm -- they have very specific requirements for the applicants to go through and do detailed site amplification studies at the sites of interests.

Those same types of studies where not necessarily done for the existing licensed plants. So what we've done is group those plans into a series of representative generic categories and used generic amplification functions to modify the hazard curves to make them appropriate for each of the different sites. And these amplification functions are both amplitude and frequency dependent.

The basis for those amplification functions was actually taken from the 1988-89 EPRI-SOG study. And they did I thought a very good job with that -- probably quite a bit better than what was done in the Livermore study. And so, we used those amplification functions. And we felt like it enabled us to make more transparent reference to the earlier 1989 EPRI results as well.

Okay. Onto the next one here.

So this is again sort of a recap of the GI-199 genesis slide. And this is actually the type of observations that the NRR staff noted when they were performing the early site permit reviews for

Clinton, North Anna and Grand Gulf and Vogtle. And this is a comparison for Vogtle. And it shows at a constant annual exceedance frequency here -- in this case 10^{-5} -- it compares the results from the ESP for Vogtle to the EPRI 1989 study. And you can see at all spectral frequencies of interest that the early site permit result bound the earlier EPRI study. And they also both bound -- at this annual exceedance frequency at least -- the SSE.

And that was essentially the observation that led NRR to promulgate this as a potential generic issue. And the issue then went into the program and was accepted in the program and screened. And that's the point where we began to -- next slide -- to perform the safety and risk assessment.

And the first step in that was the calculation of seismic hazard. So what did we need to do? We had certain requirements that we thought we had to satisfy. One, we needed to produce consistent estimates at in this case 68 different sites. The 96 different plants entail 68 different locations so we had to produce at least a rock input hazard at 68 separate sites. And as I described in the earlier slide, we tried to incorporate the site-specific geological information from the FSAR and the EPRI 1989 site amplification functions to do this.

And what we used is the 2008 version of the United States Geological Survey software seismic hazard model. This is what's used to develop the National Seismic Hazard Maps and the building codes. And I calculated it for rock site conditions and used the amplification factors to adjust it those site-specific conditions.

I should point out here that we were fortunate to have on staff in NMSS a gentleman was intimately involved in the development of that software who greatly facilitated me getting those things compiled.

CHAIRMAN POWERS: And figuring how to use the damn thing.

MR. AKE: Yes. Because there is no documentation for it.

CHAIRMAN POWERS: That's right.

MR. AKE: Only FORTRAN with a few comments.

(LAUGHTER.)

MR. AKE: So anyway, example results are illustrated --

CHAIRMAN POWERS: Let me ask you. Have you documented your experience?

MR. AKE: No.

CHAIRMAN POWERS: You got to do this. You're going to hit by a truck.

(LAUGHTER.)

MR. AKE: I have to admit that it's on my to-do list.

(LAUGHTER.)

MR. AKE: It's very true because it's something that we need to have somebody else able to --

CHAIRMAN POWERS: I mean, if they aren't going to do, we've got to do it ourselves because we've got young people coming on here who are not going to know FORTRAN from --

MR. AKE: Yes. And one of the things that I would mention as sort of a segue to some of this stuff we're doing in the research program -- our long-term research program -- this particular code only produces mean hazard results.

CHAIRMAN POWERS: Right.

MR. AKE: I mean, it actually does not produce fractal results. I mean, it computes everything but does not produce those at this point simply because of the volume of results that it produces.

I'm currently working with some of the staff at the GS, and they're revamping this as a Monte Carlo approach where we will actually produce -- for a given locale, we'd be able to produce fractals as well which I think in your earlier remark I think is something that would be of use for use to do.

CHAIRMAN POWERS: Yes. That strikes me as a very good idea. And there are very sophisticated techniques for taking these voluminous outputs and turning them into something civilized that a human being could get his hands around and what not. That strikes me as a very worthwhile activity.

MR. AKE: Yes. As the seismic hazard models become more complex, we move from being able to easily -- at this model now for a given location is in the few thousand branches on the tree. New models coming out are going to be in the million branches on the tree. And so you need to have something like a Monte Carlo approach.

CHAIRMAN POWERS: And it strikes me as one of those things that you want to flag, and next time the ACRS produces a research report to make sure that gets in as an activity that the Commission should support as we go along -- a specific activity getting your software up to snuff -- things like that.

MR. AKE: And we are developing our own software with a contractor specifically because not everyone -- those of us that are no longer in our 20s, 30s or 40s will not be around to translate FORTRAN for anyone much longer. So we need to move things to a different --

CHAIRMAN POWERS: I'm getting the impression that some of this GUI interface the Agency's developed -- the SNAF I think it's called -- is extremely flexible to facilitate use of some of these and things like that. These are kinds of things that you can think about doing and especially with the younger generation that know how to use these GUIs and what not and have no idea what a JCL card is.

(LAUGHTER.)

CHAIRMAN POWERS: Those are things that you can think about getting some support to do and it will pay off big time as those of us a little longer in the tooth disappear from the scene. That's good.

MR. AKE: The example that occur on stage left there are simply rock hazard curves for the four frequencies that we computed -- peak ground acceleration which is nominally 33 to 50 Hz in this case, 10 Hz, 5 Hz and 1 Hz -- we felt like that stand the applicable range of vibrational frequencies for most of the structure systems and components that were important to safety.

And on the right, I just show for a 10 Hz and 1 Hz, the effect of applying the site amplification functions. And you can see that say, looking at the 1 Hz curve -- the blue curves -- that across all amplitude values for this particular deep soil site, you see a significant amplification, but that you can see for the 10 Hz case as you move to higher and higher amplitudes, you actually get de-amplification. And those are important things to take into -- in the range in which those crossovers are kind of occurring turn out to be -- as Marty will illustrate a little bit later -- ranges of amplitude of interest to us.

This is just an illustration of the uniform hazard spectra. And we've computed uniform hazard spectra for each of the sites because we needed to use to develop this as a starting point for computing the GMRS -- ground motion response spectrum -- that we use as a comparison point in just a couple moments here.

And obviously, once you have a hazard curve, if you just draw a constant line parallel to the X axis and pick off the values, you have then produced a uniform hazard spectra, one that has a constant probability or a frequency of being exceeded.

A piece of information or a source of information that we used quite heavily in this assessment was the IPEEE results. The IPEEE program -- one of the external events that are considered seismic. And it also considered the implications of beyond design basis ground motions for the plants as well.

The IPEEE defined a review level earthquake -- which I'll refer to as an RLE -- whose spectra either equaled or exceeded the SSE depending upon the type of evaluation that was done in the IPEEE. There were several different scopes and evaluation that were conducted during the IPEEE, and then demonstrated plant safety by either producing a seismic margins analysis or a seismic PRA.

And we need to point out I think an important point here is the following is the emphasis in IPEEE was on developing risk insights. It wasn't on developing specific quantitative risk metrics. And so what we've tried to do is use that information to push it a little bit because it's really what we had available to us. And as I point out here that they used depending upon the plant some of them used the

1980s vintage EPRI results and some used the early '90s and the Lawrence Livermore results.

And this is a brief step here through the first part of the seismic -- or the safety and risk evaluation. What did we do? We first focused on the seismic hazard results. We took the seismic hazard results for each of the plants that we developed, and then we followed the guidance in Reg Guide 1.208 to develop a GMRS for that existing plant location. Okay? And so that follows the performance-based approach, and it focuses us somewhere between 10^{-4} and 10^{-5} with a potential adjustment factor depending on the slope of the hazard curve. So we computed that for each one of the sites.

Then what we did for each site was test that against the SSE and say, well, using this new hazard information and the approaches that we would now suggest today, is that GMRS greater or less than the existing SSE? And it turns out for about almost two thirds of the plant what we produced with the GMRS exceeded the SSE at that site.

So we next look at that relative to the review level earthquake that was used in the IPEEE evaluation. If that falls beneath something for which the plant has already been evaluated, there's no need to really consider it a lot farther there. And approximately a third of the plants, the GMRS exceeded the RLE that was used in the IPEEE.

And then you also have to recognize as you pointed out there's significant uncertainty in the estimate of hazard. And so we tested the new GMRS with -- I also computed a GMRS for the EPRI results -- 1989 EPRI results -- and the 1994 Livermore results and compared those. If it was essentially bracketed, we would somewhat argue well, it's subject to the uncertainty of doing the calculation. And it turns out that about between 20 and 25 percent of the plants, the GMRS -- the updated GMRS -- exceeded the older GMRS.

And at that point, you still have to step back and say well, is there significance to this. The hazard could go up, and really it's no risk significance. And that's essentially the -- we tested against a risk metric. And that's what Marty's going to talk about in just a moment.

And I'd like to just finish off by just very briefly making mention of the following. And this really is sort of a synopsis of the difficulty in doing an assessment like this. The total seismic margin that exists in any given plant is due to a number of different factors. We schematically tried to illustrate this here. We still struggled with the best way to try and illustrate this. But this is what we've got right now. And again, we do it with a set of response spectra.

As we described earlier, there's probably some margin in the SSE because it's anchored to the largest events observed in the region historically. And as I described, we had that transposition, we moved the event closer to the site. So there's probably in that original development of the anchor point for the SSE, there's probably some margin that implicitly comes into the process there. And then we described how the spectral shape for the SSE was developed with the 84^{th} percentile, and again some margin that again creeps into the process there.

And then when we take these ground motions and we then have to translate those into in-structure motions, typically that's done by doing a large number of realizations and enveloping some of that. So there's clearly some analysis techniques that then produce some additional margin for in-structure motions.

And we then have a design load, if you will, that we use as a starting point in our design process. And there's additional margin that comes into the process by simply following the design -- the applicable codes and standards. We don't design things to fail at the SSE. We didn't them to not fail. So there's some margin that comes in here.

The issue then is now is quantifying what that margin really is -- is arriving at an estimate of what exists at the existing plants. And we point out that because the SSEs are plant-specific, this margin then becomes plant-specific. And it's also very frequency-specific. In other words, at each of these different vibrational frequencies, there's a different level of margin as well.

And so, at the end there's some unquantified margin in all the plants. It's just inherent in the processes we use. And that makes this next stage of the analysis fairly challenging.

And that's where I hand it over to Marty so he can explain how we actually do that.

(LAUGHTER.)

MR. STUTZKE: Okay. We'll give John a break here for a little bit.

So as John pointed, we've done a lot of work on re-estimating seismic hazards for us. And the idea then is to compare the change in risk that results from using different seismic hazard curves and some sort of risk model.

And again, a summary, we have the IPEEE era curves, the EPRI-SOG data from '89, the revised Livermore data from '94. Those are kind of what we think are the baseline risks. Generic Letter 8820, Supplement 4 said either one was acceptable for identifying vulnerabilities under the IPEEE program.

One thing I'll point out is there is not an EPRI-SOG curve for every plant in the central and eastern U.S. Not all plants are EPRI members. And then some of them don't want to pay the money and participate. And so there are some plants that are dismissing like that. On the other hand, Livermore got all the plants because we paid them to do so.

In the more recent case, we have early site permits and combined license applications at co-located sites. And it's only a handful of the sites. And as John pointed out, due to the soil amplification, a hazard curve for a new plant is not necessarily the one you would use for the co-located existing plant at the same site. It's loud and clear, for example, if you look at Calvert Cliffs. And yet, it's just a half mile down the road basically, and it's like night and day. So we set those things aside.

The other thing is that we have a memorandum of understanding with EPRI for collaborative seismic research. And we actually got some information from them for six sites. Okay? It was like pulling teeth.

(LAUGHTER.)

MR. STUTZKE: And of course it's proprietary. We haven't really reviewed it yet and things like that. So we did some comparisons. And I'll make some comments about the results a little bit later. But of course, we didn't have every site that we needed. And then finally there was the U.S. Geological Survey data that John laboriously processed.

This is what this guy does on his vacation. It's amazing. I keep telling him he needs to get a real life like that.

As John had pointed out before, normally when we do a site risk assessment of a generic issue, we pick representative sites. And I got leaned on pretty hard by some managers to pick representative sites. And so my sarcastic comment was fine, I'll use the hazard curve for Sequoyah, East Tennessee. And I'm going to use a .1g from like Crystal River. And all the plants are screened in.

So it's clear you need to look at every individual site like this because the hazard curve varies so much from site to site as well as the plant level seismic fragility varies so much from site to site.

To give you an idea of that is the next slide here. This comes from the USGS website. And you'll looking at contour lines of the two percent probability of exceedance in the next 50 years. That's roughly an occurrence rate of 4 x 10^{-4} per year. And I call your attention to the green areas. That's the .1g. So that says there's a two percent chance of exceeding .1g in the next 50 years in that area like that. And you can see it covers a notable part of the central and eastern United States like that.

So that being the case, I had to come up with some way of analyzing them. And let me set the stage for this thing. There is no current regulation that says plants have to have PRAs, and certainly not seismic PRAs like those. And before we can go out and write some sort of generic communication that says please go off and do us a seismic PRA, we got to have some justification because we realize it's money and expense and things like that.

So fortunately the management directive 6.4 gives us a pretty broad latitude in how we attack a generic issue. And I think we're kept in check by the panel that Pat Hiland chairs because there's good experts from NRR and NRO on the panel that held us in.

So the way that we developed this approach was let's look at what available seismic fragility information we have. And it turns out to be around IPEEE time frame. Thirty percent of the plants did seismic PRAs. And so we actually have pretty detailed information for some of the systems, structures and components like that. What you don't have is the actual PRA model. I mean, you got a picture of the event tree and things like this. But it's not like it's an executable model to manipulate like this.

Many plants held its seismic margins analysis. And so the idea is to find a review level earthquake and associate its spectral shape. And you go through and you screen components. You define a couple of success paths in your screen components in that path against this thing. And what a typical result is, they'll says everything screened at 0.3g's. So there is no insight as o which system or structure is driving the risk. All you know is everything --

the floor -- like this.

In addition, there's very limited information on the containment performance because what the IPEEE had people do was to address things in a qualitative manner. The big one was inflatable seals on airlocks. And so you get a differential motion and maybe you punch a hole in the thing -- that sort of thing, but certainly not quantitative like this.

We also realized that since the IPEEEs were done, plants actually made modifications to address the vulnerabilities. But there's no follow-up to say what is the new fragility of the plant like this. That wasn't well tracked by us.

The other thing I'll throw in is that there's no real indepth review of any of the IPEEE results. It was done well before standards were done. And quite frankly, the staff was almost in an assembly line. Did you meet the intent of the generic letter?

CHAIRMAN POWERS: I mean, the intent -- I mean it was really to gain insights. It really honestly did not matter how well they did things, nor did you get some insight exactly.

MR. STUTZKE: Exactly. But our

expectations of quality now -- PRA quality -- are a little bit higher now. And so, this is kind of the thing. And so the next bullet here is what would prohibitive for the staff to develop seismic PRAs to analyze this issue.

CHAIRMAN POWERS: You can't get the plant information? I mean, you would just never know the plant well enough to do --

MR. STUTZKE: Yes. I mean, it would be very tough. But you're talking hundreds of millions easily to go after these things.

So thinking about that, the approach we came up is as follows. For each plant in the central and eastern United States, combine the mean hazard curve -- the EPRI-SOG, the Livermore and the USGS -- with a mean plant-level fragility curve so it's a single black box PRA that says the probability of core damage as a function of acceleration is this function. And we developed that fragility curve from the IPEEE information we have and estimate seismic core damage frequency. Okay?

When you think about, that's not necessarily the mean seismic core damage frequency. Convolution of the two means is not the mean. But it's the best we can do with the information we have.

I'll talk about that a little bit later.

The other thing is that it's fixated on core damage frequency, not release frequency or true risk to the public. And that has ramifications when we do value impact studies for cost looking at backfits and things like that. So it is what it is, and we all understand its limitations.

One of I guess the knowledge transfer chores that John and I have had during this project is trying to convince people you don't pick values off the hazard curve and pick values off a fragility curve and multiply them and say that's risk. The equation shows it's an integral quantity over all possible accelerations like that.

So in fact, that's what we did. And in order to quantify this, we looked at the PGA curves and a PGA-based fragility. We looked at a 1 Hz curve and 1 Hz fragility curve, 5 Hz, 10 Hz -- a simple average of the four numbers what we call the IPEEE weighted average. This comes out of the NUREG 1407 guidance that said you should use one seventh of the PGA and two sevenths of 1, 5 and 10 Hz. So we averaged those up. You just can simply pick the maximum of the four. And then we developed what is known as a weakest link model that's described in

Appendix A of the safety risk assessment report.

In essence what the weakest link model does is it compares the uniform hazard spectra to the review-level spectra, and it finds at which spectral frequency do you get the closest point of a curve. And that is the corresponding probability of failure. And so as John had pointed out, what you'll see is that at small accelerations, the weakest link might be at the 1 Hz spectral frequency and then it'll jump to 10 Hz at higher accelerations.

The way that they normally do seismic PRAs is to evaluate the frequency if you assume the natural frequency of the component or the structure that you're interested in. And the analysis is done like that, and that review spectral shape is then used to convert it to an equivalent PGA. And then the integral is just straightforward. Then you disintegrate across PGA.

The weakest link realizes well, the actual shape of the uniform hazard spectra is not exactly what was used to compute the fragility. Spectral shapes are different, and so you need to account for that.

There's some back-up slides if you have questions. But that's the notation. Okay.

You've seen this curve before, so this is the example of hazard curves that we use.

Plant-level seismic fragility curves -- now we're getting into the real PRA black magic to some extent. In general, you can get a plant-level seismic fragility curve is you've got a seismic PRA. You can back out the probability of core damage as a function of acceleration. And for the 30 percent of the plants, that's exactly what I did. And if you plot them out on log normal probability paper and lo and behold, it's reasonably straight. And it's pretty good.

For seismic margin plants, you have to understand how they report their results. They use the figure of merit called HCLPF -- high confidence of low probability of failure. So the HCLPF is that acceleration at which there's approximately a 0.01 probability of failure. And that's what they report is the HCLPF of the plant.

So all we did was we assumed that the plant-level fragility curve was log normal. Why not? We anchored it at the HCLPF value. We assumed the shape parameter which is known as beta C or the composite log standard deviation. We assumed it at 0.4 for that. And hence the whole curve can be generated from the two points.

We did do sensitivity studies over a range from about beta C from about .25 up to about .5. And the conclusions we have don't change.

CHAIRMAN POWERS: I think we went over that with the -- one of the earlier applications, we went through that sensitivity analysis for beta C in some detail.

MR. STUTZKE: Yes. When I actually look at what's done, they're calculating things that are log normal because they're using multiplicative models of margins and things like this. And they're estimating or questimating each one of the individual betas. And then it's the square root of the sum of the squares sort of approach to generate the whole curve.

As I said, it turns out it's not too sensitive. But remembering your earlier comments about log normal, I'm remembering there was an editorial in IPEEE transactions on reliability about 20 years ago by a guy named Ralph Evans. And he says everything's log normal if you don't look too hard.

CHAIRMAN POWERS: Yes. The log normal distribution fits everything.

MR. STUTZKE: Realize for the plants that we had seismic PRAs from, we were lucky to get a half a dozen points. And so when you plot those out on log normal paper, it's a pretty good fit.

CHAIRMAN POWERS: It's on the line.

MR. STUTZKE: It's not bad.

CHAIRMAN POWERS: And there's really very little risk I think using the log normal to go down. It's the tail high that's the problem.

MR. STUTZKE: Right.

CHAIRMAN POWERS: Because log normals are not one of your thick-tailed distributions.

MR. STUTZKE: Okay. So to try to summarize the results, these are box and whiskers plots. So the upper whisker is the maximum, the top edge of the box the 75th percentile, the green dot is the mean and the yellow triangle is the median.

CHAIRMAN POWERS: And I always just why the 75th? What is there about the 75th? I mean, the 84th, it's one -- I know what you're doing. The 75th, I have no idea. It seems like you pick the number in order to avoid going over some perceived maximum in there.

MR. STUTZKE: Yes. Well, I think the idea is quantal/quantal and just divide the range into four ranges. I mean, you could actually draw it within any number that you want like that.

CHAIRMAN POWERS: Yes.

MR. STUTZKE: This is traditional. But there's no good reason like this. And so what it shows you is the variability of the range of results when you look at the EPRI compared to the Livermore, compared to the USGS data that we got like that. And maybe you're immediately struck by the two orders of magnitude range in the seismic core damage frequencies across the --

MEMBER RYAN: But you go point to point like all the pinks or all the yellows, it looks like to me like what -- about half an order of magnitude?

MR. STUTZKE: Right.

MEMBER RYAN: When you're comparing like to like across all three.

MR. STUTZKE: Yes. Yes. From that perspective, sure.

MEMBER RYAN: Yes.

MR. STUTZKE: The other thing you'll notice is that the distributions for Livermore compared to the USGS are almost the same.

MEMBER RYAN: Yes.

MR. STUTZKE: But don't be misled. The maximum of the Livermore is not the maximum for the

USGS. And there's no serial correlation among them.

CHAIRMAN POWERS: I mean, none of this -- these ranges are about the kinds of ranges that we saw in the IPE results for internal events.

MR. STUTZKE: Yes.

CHAIRMAN POWERS: I mean, there's nothing stunning about the use as far as the magnitude of uncertainty.

MR. STUTZKE: Well, and one of the things that's a little disturbing -- I might as well discuss it now -- is I can look at the results for two identical plants at the same site, so say unit 1 and unit 2. And you get different seismic CDF results. And I asked myself why was that. In the bottom line is unit 2 was owned by one utility and unit 3 was owned by another, and they hired different contractors that made different assumptions and you get -- and it's twice as high.

CHAIRMAN POWERS: Does this stun you? I mean, you're convoluting fragility curves which is at best an art form with seismic hazard curves which is at best an art form.

MR. STUTZKE: Yes.

CHAIRMAN POWERS: I don't think I'm surprised. But can you get rid of the bad? Well, seem me in 50 years when we're a lot smarter.

MR. STUTZKE: But you've hit the nail on the head as to about how we reached the decision on what we're going to do like that.

The one reason why we like to show this set of box and whiskers is if you look at even the maximum seismic core damage frequency we calculated, it's right at 10^{-4}. Okay? And we have an NRR office instruction 504 that was developed I think after the Davis-Besse head vent that says if CDF is up around 10^{-3}, think about shutting down the plants like this.

CHAIRMAN POWERS: I think we've got an outstanding empirical definition that that is true because was it LaSalle that had the 10^{-3} kind of fire hazard analysis?

MR. STUTZKE: Yes.

CHAIRMAN POWERS: When they reported that, not only did the NRC send people on an airplane up there, the industry itself sent people on an airplane.

Clearly 10^{-3} is totally unacceptable for everybody.

MR. STUTZKE: Right.

CHAIRMAN POWERS: Industry and NRC, the plant itself. LaSalle was asking for help. And so you know that your safety has to be somewhat better than 10^{-3} in this land decades or what you'd use as the counting number. So 10^{-4} is not a bad number. I mean, we have an empirical demonstration, and it cannot be 10^{-3} because if even the industry reacts to that, we know that's unacceptable.

MR. STUTZKE: Okay. The General Issues Program has criteria that are patterned off of REG Guide 1.174, the stair step function where you have a baseline seismic CDF and a change in seismic CDF on the Y axis like this.

And when you throw the dots up on here, you see the following figure. I'll point out that there are two baselines here. One is the EPRI-SOG data and the other is the Livermore data indicated by the blue dots and the yellow triangles like this. And so sometimes plants want to be in the continue zone when you use EPRI as the baseline. But they don't want to be in the continue zone if you use Livermore. And since either curve was acceptable, we had this kind of dilemma about what are we going to do here.

But the key observation here is there are more than a few plants in the continue zone. Okay? It's not just one or two. And they're not just hovering on the line. They are clearly above our line. And we see similar results whether we used our weakest link model or PGA-based curves. You continue to generate this general pattern of results like this.

We added in the SPAR internal events core damage frequency estimates to see whether it would shift over to the right and hit that mean. And it didn't. So then I added in the fire PRA results that were in NUREG 1742 which is the summary of the IPEEE. And those aren't true fire core damage frequency estimates. They're the results of the EPRI 5 screening approach in most cases. So they're pretty conservative.

But the point is you don't kick out beyond this knee here of this curve. But again, the plot is somewhat misleading because it's log rhythmic axes which means you're only looking at the positive changes. I can't plot the negatives.

So we cooked up something called the delta-delta plot that is seen at the change with respect to EPRI-SOG along the X axis and the change with respect to Livermore. And then we redefined a continue zone that says if one of the deltas is above 10^{-5} and the other one is positive indicating it's really going up -- both indicators are telling you it's going up -- then it should in continued.

That little notch screens out the areas

where they're both are going up but they're less than -5, so that's a consistency with this previous General Issues Program. And so you see this result, and clearly there are more than a few dots that are in the continue zone. But it also shows you that some of the plants -- the seismic CDF estimate -- went down when we used the USGS data because clearly they're negative. You get some plants if you look there's a dot that is in the lower right corner that says gee, I get a tremendous change with respect with EPRI and a negative change with respect to Livermore which means the new estimate now is bracketed between the two previous ones like this, which is the sort of the behavior I wanted to get a feel for.

Now during the conduct of the safety risk assessment, we spent a lot of time deliberating on whether we should identify which plants -- I mean, every time I showed this to some manager, he wants to know which plant is in that upper right corner. Who is that guy? And we don't want to prematurely focus on it because we know our methods are a little crude, our data is out of date. And to indicate that only the plants that are in the continue zone are the ones we need to focus on is misleading. There are some of the plants in the exclude zone that are on the borderline that could easily be the other way. And so we were trying to be real sensitive to don't focus on the individual plant. Focus on the collective result here.

That being said, I'll show you the results of the plants on this map here. And I'm not spilling the beans because the NRR Director Eric Leeds had released this. I think it was at the Amelia Island conference earlier this year. And it showed up the next day in the trade press -- the list of plants.

But anyway, here they are. There's 27 plants in this continue zone. As a key, the circles are plants that are based on seismic margins, estimates of fragilities. These three triangles there at Seabrook, Indian Point and Oconee that are based on seismic PRAs. So I was looking to see if I was biased because I was using SAMA results. And the answer is not necessarily. There's no obvious relationship on geography here. I mean, if I go to Eastern Tennessee -- Watts Bar, Sequoyah -- we know the seismic hazard estimates are higher there. And that's probably why these plants show up on there.

On the other hand, you look around the Gulf Coast -- Crystal River, St. Lucie, Riverbend -- that's because when they did their seismic margins, they did what was called a reduced scope where the review level earthquake was equal to the safe shutdown earthquake. In fact there was no margin added in there at all. So that's probably something that could readily be analyzed.

So it's interesting. The other thing is that there's not a correlation here among the type of plants. I've been resisting the urge to correlate it to the IPEEE contractor, but since my name would be scattered all over the map I didn't want to embarrass myself or potentially Dr. Bley and Mr. Stetkar since we were all heavy business competitors at the time.

CHAIRMAN POWERS: Now I want it.

(LAUGHTER.)

CHAIRMAN POWERS: This could be very useful, Marty.

MR. STUTZKE: Yes. I've been curious at times.

So to kind of wrap this thing up is we have more than a few plants -- it's about 25 percent of the plants -- want to be in the continue zone right now. And you got to ask the question. So what are we going to do about it? Or do we want to go like this? And specifically, should we consider backfits?

As you know, there are basically three

types of backfits -- those that are required to achieve adequate protection, those that are required to bring facilities in compliance, and the cost-justified backfits that provide substantial safety enhancements. And those need to be justified through the use of value impact studies.

So what I've showed you here is a table that comes out of our regulatory guidance -- NREG/BR-0058 -- that does the initial screening based on safety goals. So it's looking at the change in core damage frequency on the Y axis that could be achieved by a backfit. The column here is conditional containment failure probability. On the left-hand side -- the gray box -- is the range of the results. That's the box and whisker plot.

So clearly we're in the bottom two rows of this table. And we leaned towards the CCFP value of .1, not knowing anything that would justify it. So it's telling us yes, we should probably be in cost benefit space to go ahead and do this.

Now, that's a daunting problem when you think about it because when we do value impact analyses, what it means is you need numbers like off-site dose so you can get averted person-round or averted person off-site costs, et cetera. And to do that, you need a level three PRA. No doubt about it.

Then that raises the complexity of the analysis substantially. As a minimum, you've got to go after the containment seismic performance like this. And I've seen analysis of containment seismic performances that are basically fine on element where they modeled the shell.

And I ask things like well, what about all the penetrations? I've got hundreds of penetrations in the plant and they could all be moving. And well, it's not really analyzed like this. And you begin to think about well, what's the impact on the level three. Can people actually evacuate? What's going on here? Some work that John did like this. But I think it's an unresolved sort of question.

One of the things that we could do is this handbook actually gives us values that says if delta CDF is this, multiply it by the scaling factor and the off-site averted costs are how many million bucks. That's developed out of information from NUREG 1150 which is pretty dated. It's a limited number of plants. And I'll point out it's calibrated to the internal event results, not the seismic results. Okay? So that doesn't mean we could do it. But I don't know if that's the right answer.

So the next thing I did was I looked at all of the SAMA submittals as part of the license renewals to see how were they treating them because if you look at a SAMA -- a severe accident mitigation alternative -- it's a cost benefit study. There would be proposed modifications to the plant. You compute the change in risk and you monetize it. Okay?

Well, there are some plants that have actually done seismic PRAs. But the general way that a SAMA analysis is done is you look at the change based on an internal events model and you multiply it up usually by a factor of three or two or 2.7 -- whatever the licensees say it will justify. And that's all okay. And then the staff has accepted that position. The problem is it's not specific to the seismic aspects that we're after here. It wouldn't get things like evacuation or seismic containment performance or things like that. So I've got concerns about -- my first thought was a lot of the plants here have already undergone license renewal and we've got level three studies for them and life would be easy for us. But I'm not convinced it's going to be that easy. There could be some benefit like that.

The other problem that I have here when you think about backfits is you've got to ask yourself well, what are you going to fix because the way that our process works is the staff should identify what the backfit is, Mr. Licensee, and we've justified it. You tell us what it's going to take to implement it and then we'll do the calculation. Well, we don't have any insight into anything we've done so far with the plant-level fragility curve. We have no idea. And then with the seismic margin approaches and everything being locked off --

CHAIRMAN POWERS: That's probably the most important point that you've made.

MR. STUTZKE: Right. I mean, there's no risk insight.

The point is it won't be a generic backfit either. It's like 20, 25 individual --

CHAIRMAN POWERS: It has to be plant-specific no matter what it is.

MEMBER RYAN: You made them do it but --

CHAIRMAN POWERS: They're no better shape than you are.

MEMBER RYAN: I was going to ask you a few minutes ago, is there anybody else in the world -- any other country or group addressed this in any useful way?

MR. STUTZKE: I came across a paper

earlier this year where the Swiss were looking at seismic level two PRAs. And they were going --

CHAIRMAN POWERS: And the Swiss have done a lot on the seismic hazards to their plants. But they're the only European country.

We did have our meeting for the quadripartite with the Japanese, the French and the Germans dealing with seismic issues. And at least the European countries, they have a completely situation than we do. And it's very different. The world looks just extremely different to them with respect to the seismic hazards for their plants.

MEMBER RYAN: How about Japan?

CHAIRMAN POWERS: In Japan, of course, what they're finding is that their seismic hazards are very different than certainly the east coast of the United States -- much more similar to the west coast with lots of disclosed -- previously undisclosed faults emerging and things like that. And they're doing a much more aggressive characterization. But I think they're still going to have this problem of faults suddenly showing up that nobody knows about. And I think they think it too.

John, maybe you know more about that.

MR. AKE: No, that's exactly correct.

CHAIRMAN POWERS: And the only thing I got out discussion in Japan was that when we go to the -- what is it -- 1742 that's the summary of the IPEEE?

MR. STUTZKE: Yes.

CHAIRMAN POWERS: You get a ranking of the vulnerable items in a containment. And you compare them to what they saw at the northern Japan earthquake at their --

MR. STUTZKE: Yes.

CHAIRMAN POWERS: There's not a lot of correlation. In fact, you see things that are up our top actually would have been down low and vice versa.

MR. STUTZKE: Yes.

CHAIRMAN POWERS: The other thing that you see in there is that seismically-induced fires definitely occur. And we've been ignoring that for a long time.

MR. STUTZKE: Yes.

CHAIRMAN POWERS: Because I think --

MR. AKE: Yes. But to couple it is difficult, and that's partly why.

CHAIRMAN POWERS: Yes. We don't know how to do it. But they clearly had seismically-induced fires.

MR. STUTZKE: Sure.

CHAIRMAN POWERS: And the other thing speaking of penetrations where you have structures -- big structures that are separated spatially, that interface between the two gets highly flexed. Really interesting.

MR. STUTZKE: Yes.

CHAIRMAN POWERS: I don't know what to do about it. But I mean what you hit upon here I think is the single biggest point. Okay, it's clearly of interest to look at can we improve the seismic safety of it. We don't what to do.

MR. STUTZKE: Right.

CHAIRMAN POWERS: And we don't have any clean mechanism for getting at it.

I don't know that we've ever done an honest analysis of core degradation in a post-seismic environment of a plant. We've always assumed that if you have a seismic event, then the accident progression is just like it would be for an internal event initiated by internal processes. I have no reason to think that's true for a seismic event that's big enough to actually induce core damage. I can't imagine that core looks the same as it does for a station blackout. It would stun me if it did.

MR. STUTZKE: Yes. Yes.

MR. AKE: But it's just what you said. That's what we have available to us and that is what we're going to end up assuming and using, yes.

CHAIRMAN POWERS: Very interesting point. And a good point. I would not make that just orally. I would highlight that. Now what? Good point.

MR. STUTZKE: That's why we have NRR.

CHAIRMAN POWERS: Yes, yes. Hey, you guys should -- it's like the old famous lookout block in football. Look out.

MR. STUTZKE: Well, one of the things that we thought about, if you go back to say look, we'll try to improve the plant level HCLPF values so that we lower the seismic core damage frequency down, let's ignore the level two and the level three that we don't know how to do too much. But we have some confidence.

If we could decide some sort of cost benefit criteria, then we could focus on the HCLPF. And the notion here was the first couple of IPEEEs I picked up gave me this nice rank ordered list of this is the lowest, weakest HCLPF in the plant, so forth and so on like this, I thought well, that's easy. We'll just fix the worst ones until we get it better. And then I remembered that isn't the way that a seismic margins is actually done. It's the max or the mins.

So this is a little cartoon to illustrate this. And I usually catch one or two people in the audience. But what do you do in this case? And the answer is you fix C because that's what's controlling the HCLPF. And that isn't necessarily the component with the smallest individual HCLPF like this.

I had mentioned before if we used the seismic margins approach like that, when I picked up the other ones and I looked at them, I didn't get this nice sort of list. The answer was everything's above the review level earthquake of 0.3 g's.

CHAIRMAN POWERS: Yes.

MR. STUTZKE: End of discussion.

CHAIRMAN POWERS: Yes.

MR. STUTZKE: So there's just no information. It's like okay, I can't go to REG analysis now. I'm stymied.

So in order to get to the REG analysis -- the next slide -- we're interested in looking at the updated site-specific hazard curves.

I had mentioned before we actually got six sets of hazard curves under our MOU with EPRI. And we computed them as well. And in two out of the six, they generated higher core damage frequencies than we generated using USGS. I don't know whether that's unique. But the trend is -- it makes you curious.

As John had pointed out, we need to have the frequency-dependent site-specific amp functions to use better like this, plant-level fragility information and specifically the contributors to seismic risk. And I used risk in its full context because that could well be containment-related systems. It could be off-site. It's really what do you want to go fix here like this. So it's clear we're going to have to do something for the plants that only have seismic margins work.

The last point that we want to point out or emphasize -- and John had pointed it out before when he was talking to you about regulations -- we have no mechanism in place that says we need to evaluate new hazard information when it comes in. Okay? And that's true not only for seismic hazards but all sorts of natural phenomena like this. And we're interesting in evolving that somehow -- that concept.

CHAIRMAN POWERS: Well, we have a quasi-commitment, I think to do that because during the ESP discussions for four plants, we raised the issue of we have meteorologists telling me over and over again that if we're not headed in global warming, we're certainly into global weather cycles. And yet, we use the past data to tell us what weather threats.

And I said what are you going to do about that. And they said well, if we see things changing, we'll come back and re-visit it, which tells me they're figuring out how to evolve things in the regulations which otherwise right now when you get a license, it's a license to kill -- which one -- because the weather standards are fixed.

So there are other fronts where we have this problem at least potentially, though here I think it's a lot clearer -- more quantitatively expressed.

MR. STUTZKE: As Lauren had said, it's because we had some heads up reviewers at NRR that identified this issue for us.

MEMBER RYAN: Marty, if you had to rank order those bulleted items as reducing uncertainty or improving predictability, how would you rank on a guess just an X dollar amount to spend? Which would you spend first?

MR. STUTZKE: Contributors to this.

MEMBER RYAN: Yes.

MR. STUTZKE: We have to know what to fix.

MR. AKE: It's probably the others -- or

at least the first two -- are decimal dust compared to that anyway in terms of the expenditures.

MEMBER RYAN: So that on the plant-specific contributors is where the action is in terms of really reducing uncertainty and improving predictability.

MR. STUTZKE: Yes.

MEMBER RYAN: Okay. Thank you.

MR. STUTZKE: That's the important thing.

Okay. I'll turn it over to Pat.

MR. HILAND: Well, we talked a lot about how we got to my one slide.

(LAUGHTER.)

MR. HILAND: This is a long slide.

And first, I'd like just to refresh our memories on where we've been for this subject. As Marty and John spoke, this has been around for several years. Mr. Goutam Bagchi sitting in the back of the room was the initiator of the question about five years ago. And now where do we head?

Two years ago, we had a public meeting. The representative from industry NEI -- Nuclear Energy Institute -- offered to facilitate some gathering of information. And that's when we entered into our memorandum of understanding or agreement with EPRI.

Actually we added an addendum to the existing agreement. And we worked with them for over a year to come up with the analysis that we have in front of us in that report.

I know nothing about seismic world. I was selected as the chairman because I think I answered the phone call that came over to NRR. And I learned a lot though over the past two years. And the report that was done was a very, very good report.

So we had a second public meeting. And I think it was early October. And in that public meeting, we discussed the same kind of information that we've discussed today. And I believe I had a commitment to make a decision by the end of this year as to what was the generic communication route that we were going to take. And that will be a generic letter.

Mr. Kamal Manoly, my senior advisor in our Division of Engineering is in the process of crafting our first draft. As you know, a generic letter has a number of hoops that it has to go through. We'll craft it. Eventually it'll go through our CRGR -- Committee to Review Generic Requirements. It'll go out for public comments. It'll come back to the ACRS before we sent it out to request information.

I think what we heard is that there's some information that would be readily available from those plants that have developed their seismic PRAs. And we know at least six have information that we could find useful.

And the reason we've taken the pace that we have is we didn't want to scream wolf all along. I mean, we could have cried wolf three years ago, and we really didn't have sufficient information. However, we did have a question. I think the seismic risk numbers of probability went from 10^{-5} to 6×10^{-5}. And if I can quote Goutam on that memo he wrote, he said it's not insignificant -- the increase. And so that's why we went down this path.

I think industry in the last late winter, maybe the early spring of this year communicated that in order for us to ask for this information, they needed a letter. And so I'm going to work on sending them a letter and asking for the information.

That's about where I think we're at and where we're headed. I don't know the end results. I suspect that if I'm a plant that has done a seismic PRA and maybe I'm one of those 29 with a triangle, I might freely provide that information and take a hard look at it to make sure I feel comfortable with my own analysis. So hopefully, we'll get some good information. That's where I'm at.

CHAIRMAN POWERS: It's difficult for me to -- I mean, we're beached on a lack of information right here. Is that a fair characterization?

MR. STUTZKE: Yes.

CHAIRMAN POWERS: And so I guess the answer is let's get some more information.

MR. HILAND: We'll have to ask for what information is available. Then we'll have to go back and look at it to see for those sites that provide it, what's the benefit for them -- what's the pay back.

And so the ones that it's not available, we'll have to go down a different path.

CHAIRMAN POWERS: I mean, we're still dealing with circa 10^{-5} event here. So it's not like the world's about to explode on this. That's correct. On the other hand, it's a 10^{-5} event. I think what I'm using is a 10^{-5} event. But I view it as a 10^{-5} event.

MR. HILAND: Right. I think the way I characterized it -- and I have a lot of experts to correct me if I'm wrong -- is that this is not a licensing basis issue. This is an issue where the risk that's apparent to us is such that we should look at it a little closer.

CHAIRMAN POWERS: You make a good point there. And there's another point that comes to mind is that in these plants that you've identified on your map, if I imagine a significant earthquake at any one of them, I've got a substantial societal impact, not because of the nuclear power plant, but because the industrial infrastructure that's around many of those plants. And I wonder what the other federal agencies thinking about like FEMA think about these issues and how they're approaching them.

MR. AKE: I can speak for some of the other agencies. And some of the other agencies are struggling with the same questions that we are struggling with which is given that many of the designs and the design philosophies were many decades ago and a very deterministic evaluation, how do I now parse that into making risk informed decisions? They're asking some of the same questions.

CHAIRMAN POWERS: I think they've got the same problem.

MR. COE: We're going to find out a little bit more when we go through the national level exercise coming up this coming up.

CHAIRMAN POWERS: Okay.

MR. COE: Which will be a seismically-related scenario.

CHAIRMAN POWERS: Okay. Okay. So we go on.

PARTICIPANT: I think we have Mr. Bagchi.

MR. BAGCHI: I just wanted to --

CHAIRMAN POWERS: You've got to identify yourself. You know this.

MR. BAGCHI: I'm Goutam Bagchi. I'm with the Office of Nuclear and New Reactors.

I just wanted to make an observation as an example. The U.S. Bureau of Reclamation is wrestling with an even more difficult problem. And they have been trying to do something. They prepared the report from the University of Utah with collaboration of many, many, many experts. This is on dam failure.

But I really felt that the work that has been done so far is just very high level, high quality and the matrices that have been presented are something that we can really work on.

And I congratulate RES for doing an excellent report.

CHAIRMAN POWERS: It's really a very, very nice pitch -- an eye-opening pitch.

MR. HILAND: Mr. Powers, if I could just

add on to Goutam's comment there. He brought up the DAM. And there is an interagency committee on dam failures -- on dams. And that just happens to reside in my division. I actually have the --

CHAIRMAN POWERS: You really got to quit taking the short one when they pass out straws.

MR. HILAND: But we do have an official dam safety officer. And it used to be Mr. Bagchi, but now it resides in my division. And we just got done with an interagency conference for two days. And we're a small piece of that. But we do have nine dams that we're responsible for to go out and inspect every couple, three years on each of those nine dams, both in the power plants as well as the fuel cycle area.

And so that is one example that you could put in the back of your minds where the federal agencies responsible for similar activities do get together, and we trade information and we keep up to date.

CHAIRMAN POWERS: Good example. Good example.

MR. KAUFFMAN: Oh, and I might add, there's also been a proposed GI on dam failures that is going to be screened here in the near future. It's related to the common theme of update to external hazards.

MR. HILAND: I think I've disconnected my phone.

(LAUGHTER.)

MR. STUTZKE: I might take your advice, Pat.

MS. KILLIAN: We have just one last slide. So just as a recap, these are the key points to take away from the presentation.

First, operating power plants are safe. Seismic hazard estimates have increased at some sites. And assessment of Generic Issue 199 will continue. Information is needed and review your questions.

CHAIRMAN POWERS: Well, I certainly found this very enlightening. I think the full Committee needs to hear this at some point. I think it's probably when you get your generic letter, because it'll have to come I think they can --

PARTICIPANT: In fact, it comes back through the ACRS.

CHAIRMAN POWERS: And I think we need to alert the ACRS to plan a substantial background on this. And I will volunteer to help you craft that background discussion. From what I know about the Committee's background and -- you're going to have a highly diverse, you're going to have Bley and Stetkar who will argue with you over the third decimal point in your analysis. And you're going to have members that have never thought about a seismic event in their life. And so we may have to work a little bit on how to craft that background.

I really like where you're stuck because that's being stuck. All right. I mean, I certainly agree with that.

Sir, any comments?

MEMBER RYAN: Yes, I think I would suggest to you that we break the presentation of the full committee into two pieces. One would be much this kind of a background with the idea that you will have the generic letter sort of in your heads and getting ready for that, and then I'd have the generic letter maybe be a second. Or let everybody kind of digest the background information. So --

CHAIRMAN POWERS: Okay. So you're saying to do it and not separate it substantially.

MEMBER RYAN: But maybe one month and then the next month so they can digest the volume of information. Because like you say, to many --

CHAIRMAN POWERS: That is really a good suggestion.

MEMBER RYAN: Thank you. I'm done. See you later.

(LAUGHTER.)

CHAIRMAN POWERS: That's an approach I hadn't thought about. But there is merit in that kind of an approach because of the complexity of the analysis and the newness to some of the analysis. There might be virtue in thinking about doing them phased in time.

MEMBER RYAN: Yes, I would do it. Marty, you do a really nice job of kind of taking all the complexity and boiling it down to the essence of what's important and not. So I think if they had just the time to think about that, maybe go back and read some background documents and get comfortable with all of that, then the idea of looking at the formal generic letter itself would be a little bit better informed.

The other thing I would suggest of course is if we couldn't get Bill Heinz here today as our consultant on this, but getting him up to speed with where you are and having him help the Committee some I think would be useful as well.

CHAIRMAN POWERS: I think Bill helps us much more in the details of the seismic portion of the analysis. That's not where the action is. The action comes forward when you try to apply it the plan.

MEMBER RYAN: Well, that's true. That's true.

CHAIRMAN POWERS: And --

MEMBER RYAN: But having Bill around might be a help to some --

MR. AKE: We'd be happy to sit down with Bill and go over this.

CHAIRMAN POWERS: What we are definitely going to ask is to try to solicit Bill's opinion on the written material you submitted and get his input. And certainly if he provides written input, we're going to share that with you because he has a little bit of experience in this area. But I don't think he has experience in the heart of the issue which is when you come in and start rattling and shaking around on the plant and what do you do about it and what do we do about our general unfamiliarity here.

That's good. Boy, that is really a nice -- he's done a nice job. This is definitely good information.

MEMBER RYAN: So when are you going to tackle a tough problem?

(LAUGHTER.)

MR. MUNSON: May I make a brief comment before --

CHAIRMAN POWERS: Go ahead.

MR. MUNSON: My name is Cliff Munson. I'm at NRO.

I'd just like to add that we're churning out new seismic source models for the COLs and ESPs even as we speak. So the generic letter may be -- the timing of that may be similar to when these new source models are ready. So this is all in flux. So having a mechanism to go forward and deal with this problem because continuing the hazard is continuing to evolve.

CHAIRMAN POWERS: Any other comments people would like to make?

(No audible response.)

CHAIRMAN POWERS: Well, again thank you, Lauren, Marty, John, Patrick, and John especially. Doug we don't thank.

(LAUGHTER.)

MEMBER RYAN: Thank you anyway.

CHAIRMAN POWERS: That was definitely worth our time. And I will probably alert the Committee during the full Committee meeting that they need to hear about this, and we will look to you to help us define a time when we do that. And I would suggest that it's sometime contemporaneous with the generic letter. And we will certainly pay attention to Dr. Ryan's suggestion. And maybe we want to do t his in a couple of steps rather than try to cram it all together at once because of the variability and background of the Committee. They all need to think about this. But they don't all have the same background.

And with that, I'll bring the meeting to a close. We are adjourned.

Thank you very much.

(Whereupon, at 4:28 p.m., the hearing was adjourned.)

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STATUS OF GENERIC ISSUE 199:
Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants

ACRS Siting Subcommittee Presentation

Marty Stutzke, Jon Ake, and Lauren Killian (RES)
Pat Hiland (NRR)

November 30, 2010

Generic Issue 199
Presentation Agenda

- Generic Issues Program Overview
- The GI-199 Safety/Risk Assessment
- Path Forward
- Subcommittee Discussion

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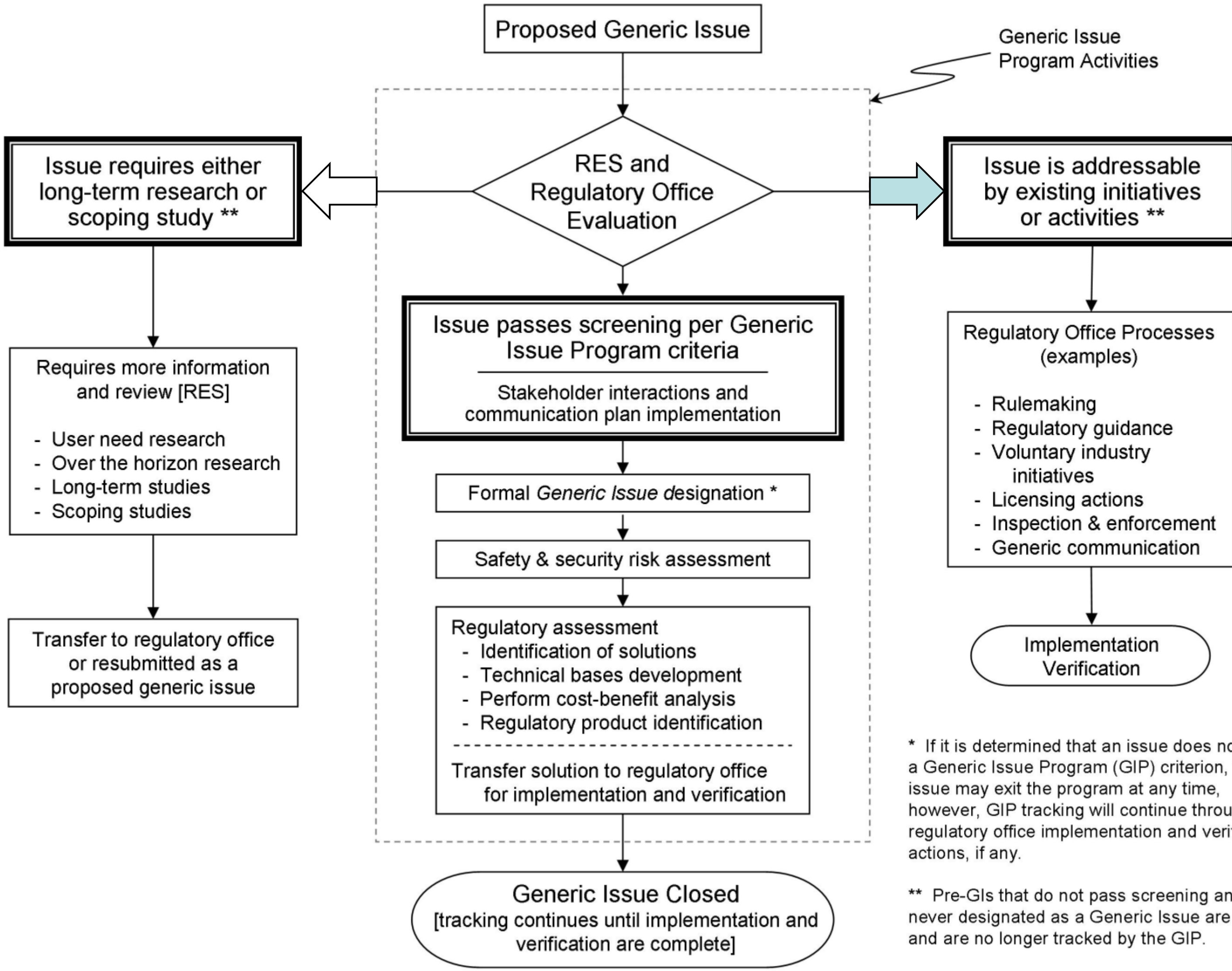
Generic Issues Program (GIP) Overview

The GIP Stages

1. Identification
2. Acceptance
3. Screening
4. **<u>Safety/Risk Assessment</u>**
   - Issue Analyzed
   - Paneled, Report Issued
   - Recommendations Endorsed
5. Regulatory Assessment

The GIP in perspective with other Regulatory Programs and Processes



* If it is determined that an issue does not meet a Generic Issue Program (GIP) criterion, the issue may exit the program at any time, however, GIP tracking will continue through regulatory office implementation and verification actions, if any.

** Pre-GIs that do not pass screening and are never designated as a Generic Issue are closed and are no longer tracked by the GIP.

Safety/Risk Assessment for GI-199

"Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants"

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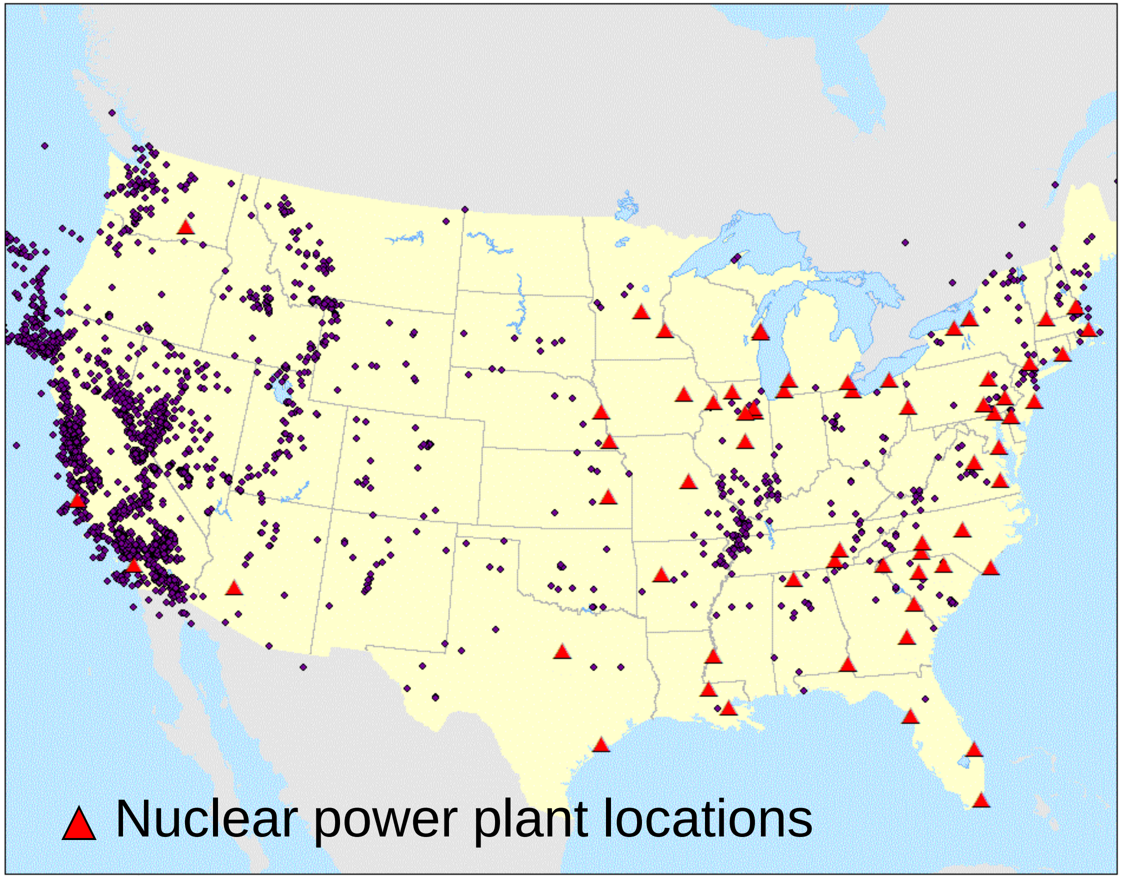
● Felt and Damaging Earthquakes In the U.S.

Source: USGS



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The GI-199 Safety/Risk Assessment

- Safety/Risk Assessment (S/RA) Stage Goals:
  - Determine, on a generic basis, if the risk associated with GI-199 warrants further investigation for potential imposition of cost-justified backfits.
  - Provide a recommendation regarding the next step (i.e., continue to the Regulatory Assessment for identification and evaluation of potential generic, cost-justified backfits, be dropped due to low risk, or have other actions taken outside the GIP).
- S/RA: Background, Approach, and Results

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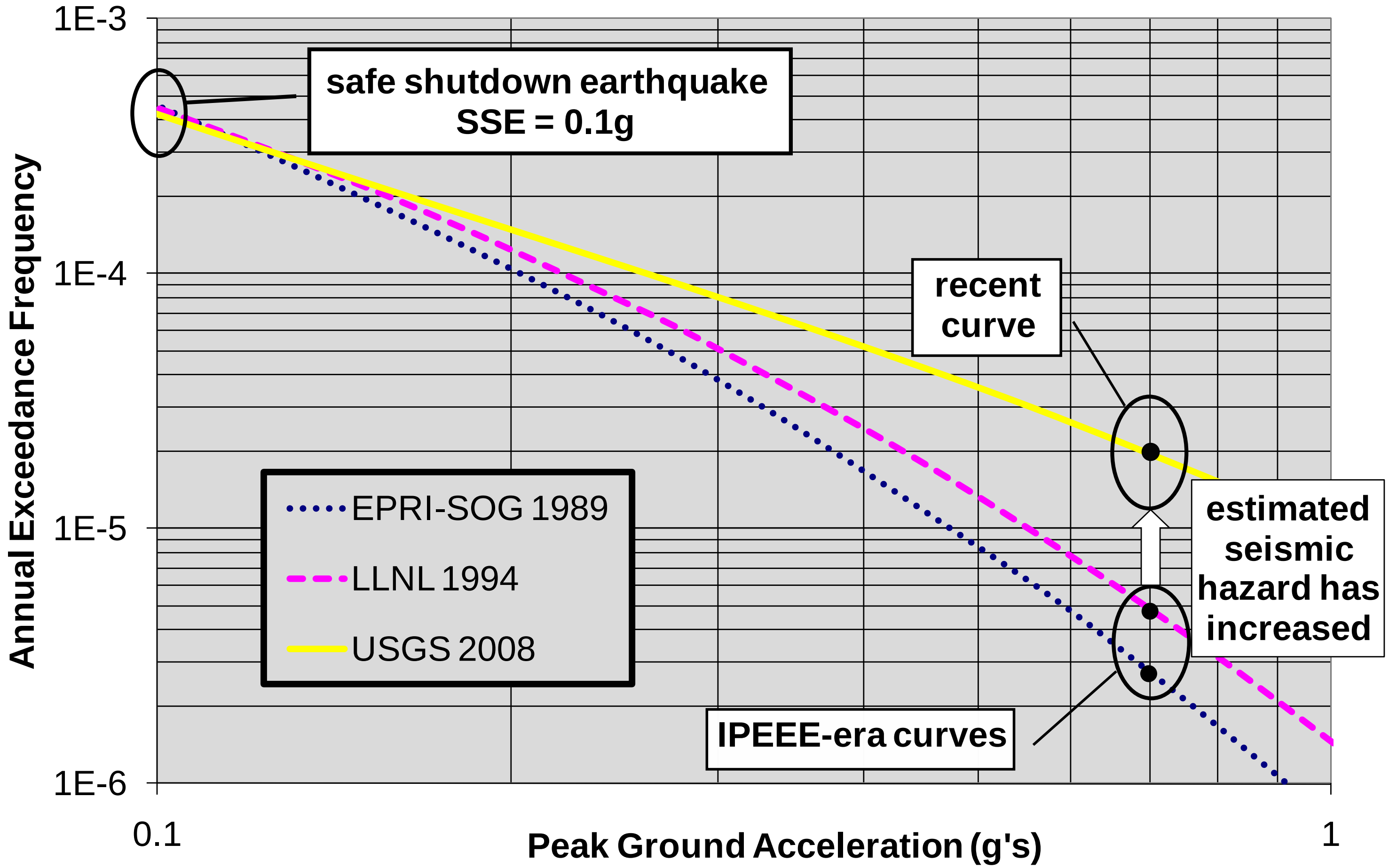
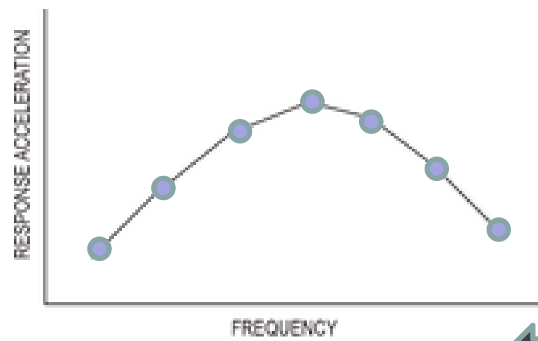
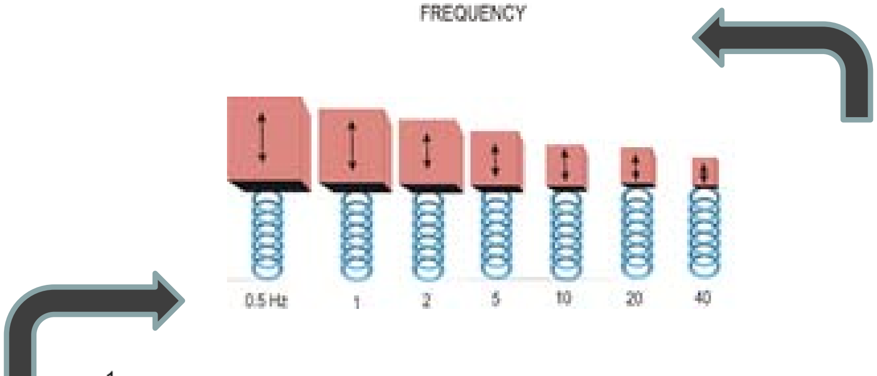
What is GI-199 About?

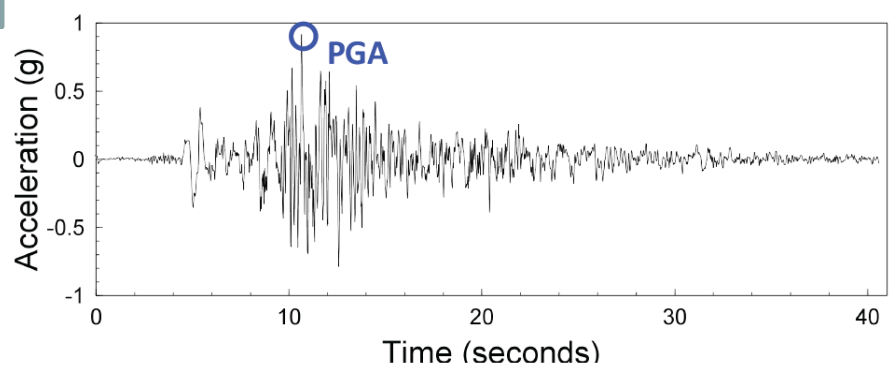


Response Spectrum

A plot of the peak response of a series of SDOF oscillators of varying natural frequency driven by the same input motion







Widely used in earthquake engineering to analyze the performance of structures and equipment and in design

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Applicable Regulations (pre-1997)

- **10 CFR 100.10(c)(1) and Appendix A establish the seismic design basis for plants licensed before January 10,1997 (i.e., currently operating plants):**
  - **Based on a review of earthquakes that have occurred nearby the site**
  - **A deterministic approach- no specification of frequency of occurrence**
  - **Different approach than probabilistic seismic hazard assessment (PSHA)**
- 10 CFR Part 50, Appendix A, GDC-2 and similar principle design criteria require that SSCs be designed to withstand the effects of natural phenomena without loss of capability to perform their safety functions:
  - **Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area**
  - **Include sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated**
- No requirement for periodic reassessment of the seismic design basis.

Determination of the Safe Shutdown Earthquake (SSE)

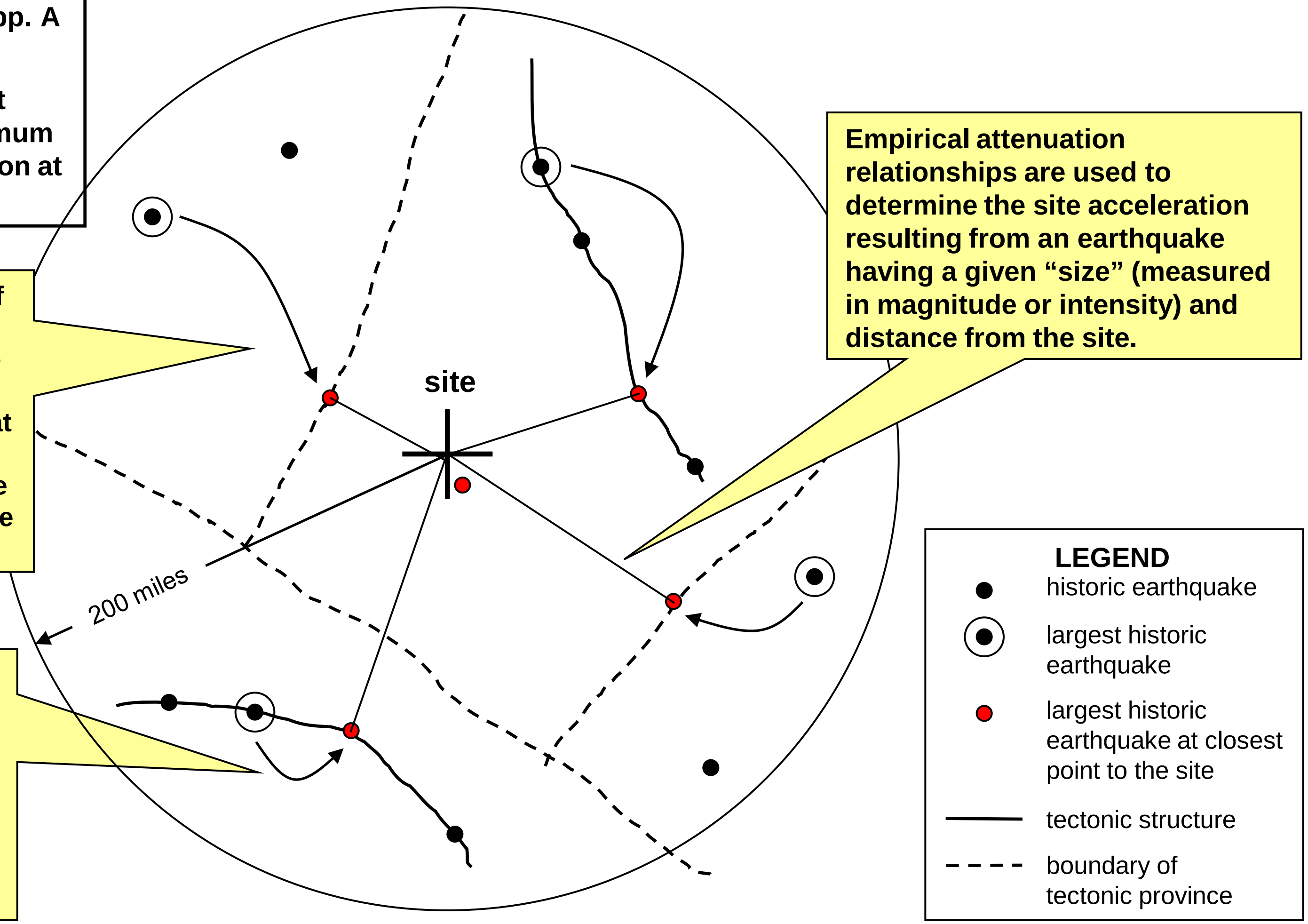
10 CFR Part 100, App. A

The SSE is the earthquake that provides the maximum vibratory acceleration at the site.

When the epicenter of the largest historic earthquake cannot be related to a tectonic structure, assume that the epicenter is at the closet point to the site on the boundary of the tectonic province

Empirical attenuation relationships are used to determine the site acceleration resulting from an earthquake having a given "size" (measured in magnitude or intensity) and distance from the site.

For tectonic structures, assume that the epicenter of the largest historic earthquake is situated closet to the site



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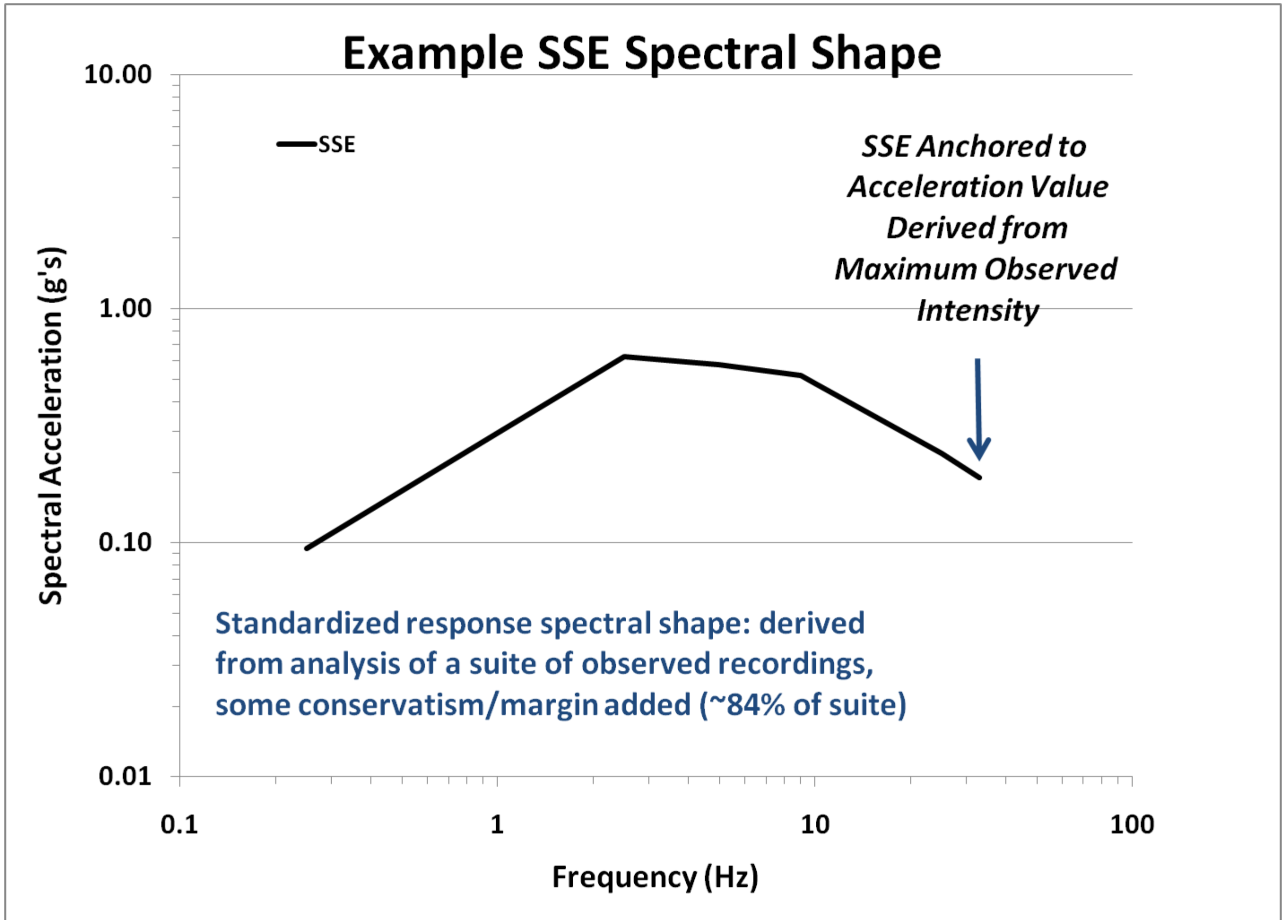
Safe Shutdown Earthquake (Ground motion)



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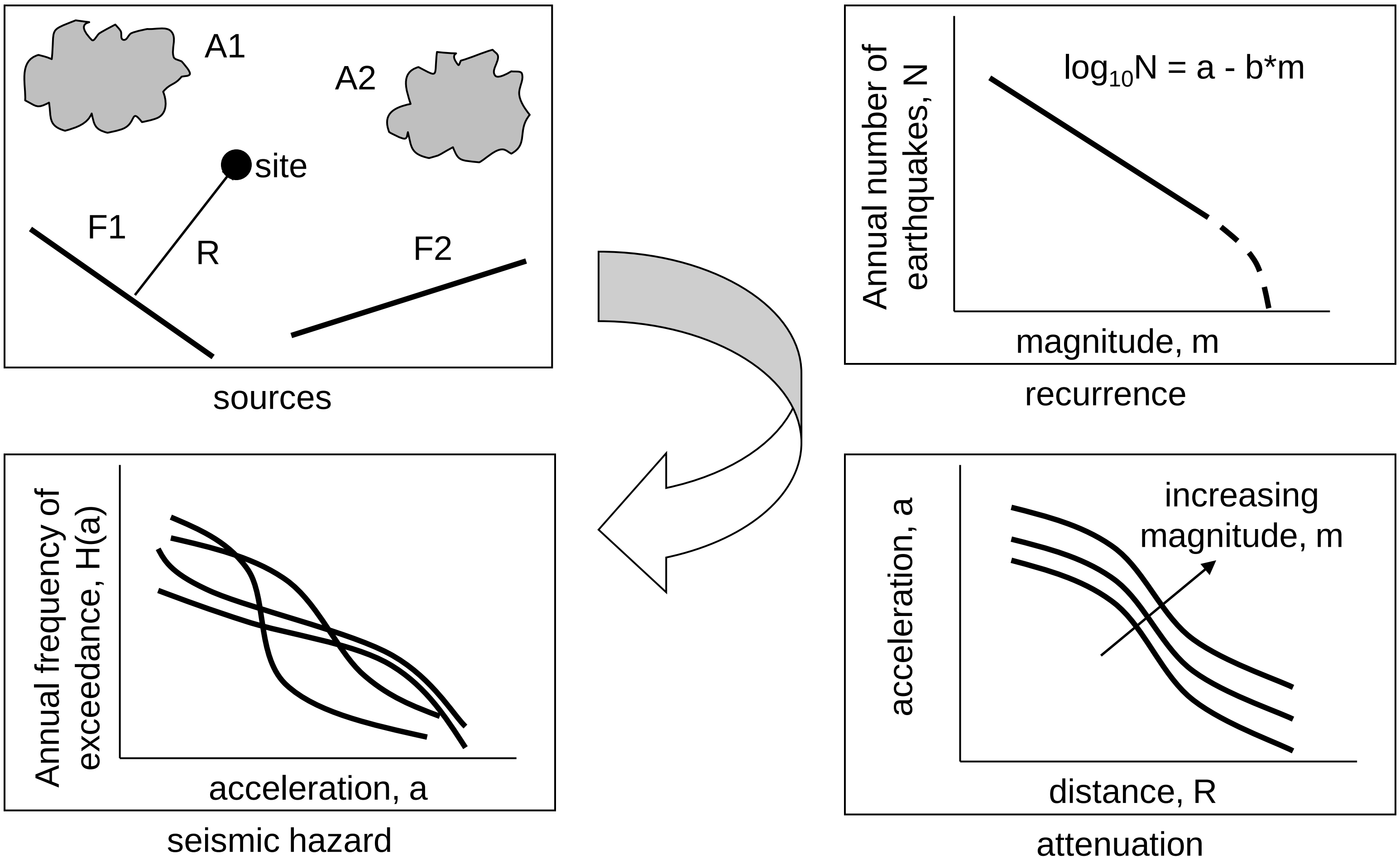
Applicable Regulations (post-1997)

- **10 CFR 50, 100.23 and Appendix S establish the seismic design basis for plants licensed after January 10,1997:**
  - Appendix S defines SSE as *"Safe-shutdown earthquake ground motion* is the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional"
  - 10 CFR Part 100.23 "Geologic and Seismic Siting Criteria" requires that the applicant determine the SSE **and its uncertainty**, the potential for surface tectonic and nontectonic deformations.
- RG 1.208 provides guidance on satisfying 10 CFR Part 100.23, one of which is performing a probabilistic seismic hazard assessment (**PSHA**). Determine (GMRS) SSE using the performance-based approach. Specifies target frequencies of exceedance linked to performance goals.
  - Different approach than deterministic Appendix A process:
    - **PSHA is a major input to seismic risk evaluation using SPRA or** SMA
- No requirement for periodic reassessment of the seismic design basis.

Seismic Hazard Model (PSHA)



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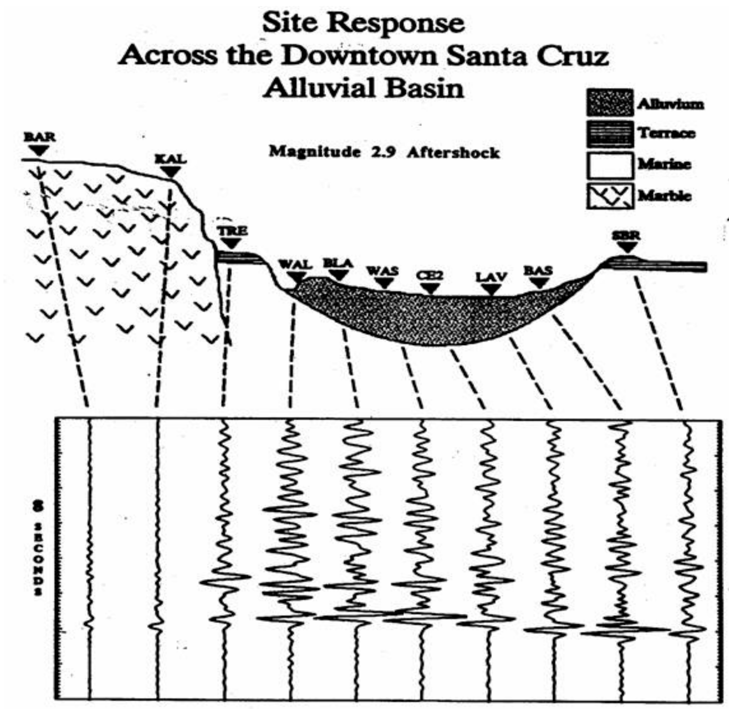
Site Response Effects (Amplification Functions)

The type and thickness of materials near the ground surface has a strong influence on the strength of ground shaking observed at a particular location

GI-199 used a generic approach to estimating site specific amplification functions (Amplitude and frequency Dependent)

Based on EPRI-SOG 1988



USGS

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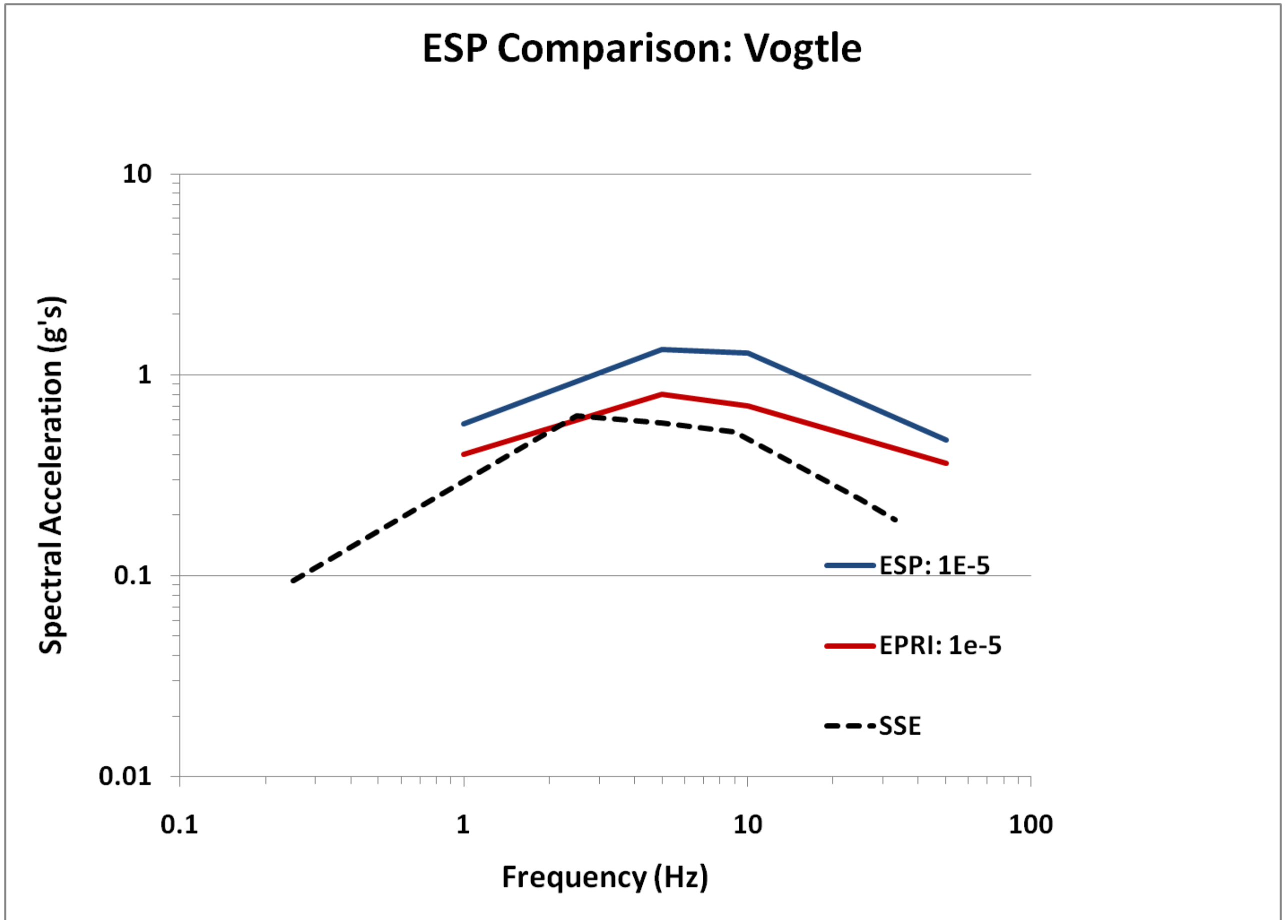
Observations From ESP Reviews



Calculation of Seismic Hazard

- **Requirements:** produce consistent estimates for 68 different sites across the CEUS.
  - Incorporate site-specific geological information.
- **Solution**: utilize the 2008 USGS software used to develop National Seismic Hazard maps. Calculate for rock site conditions, adjust to "site specific" conditions.

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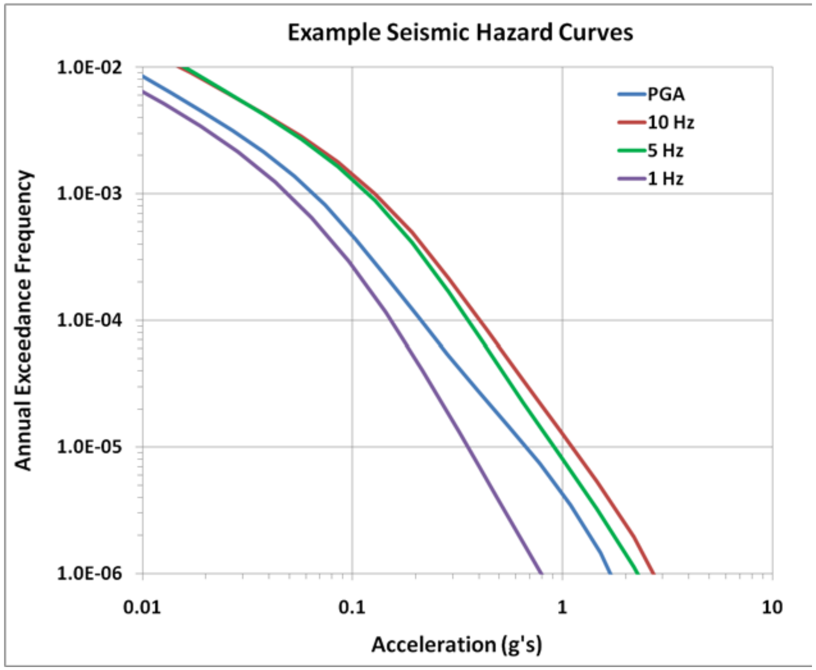
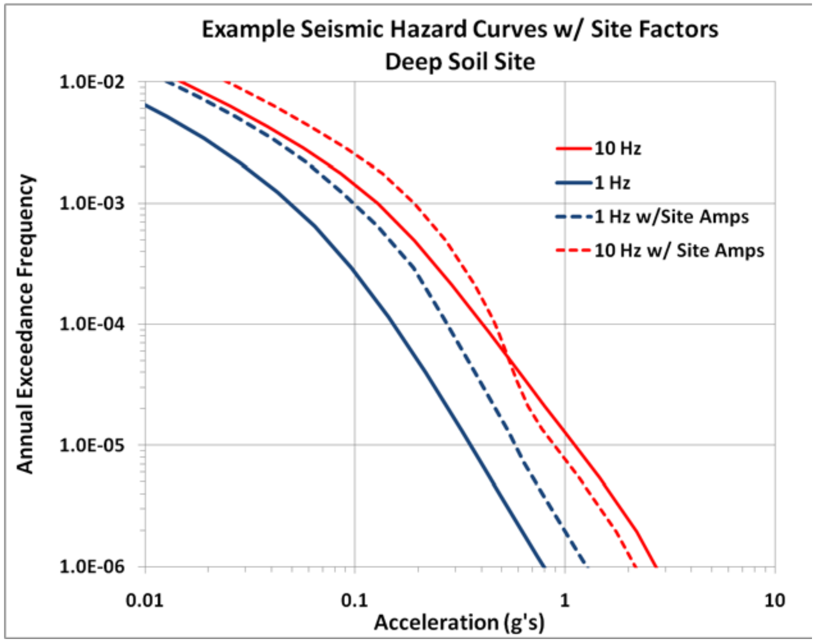
Seismic Hazard Results- For Each Site





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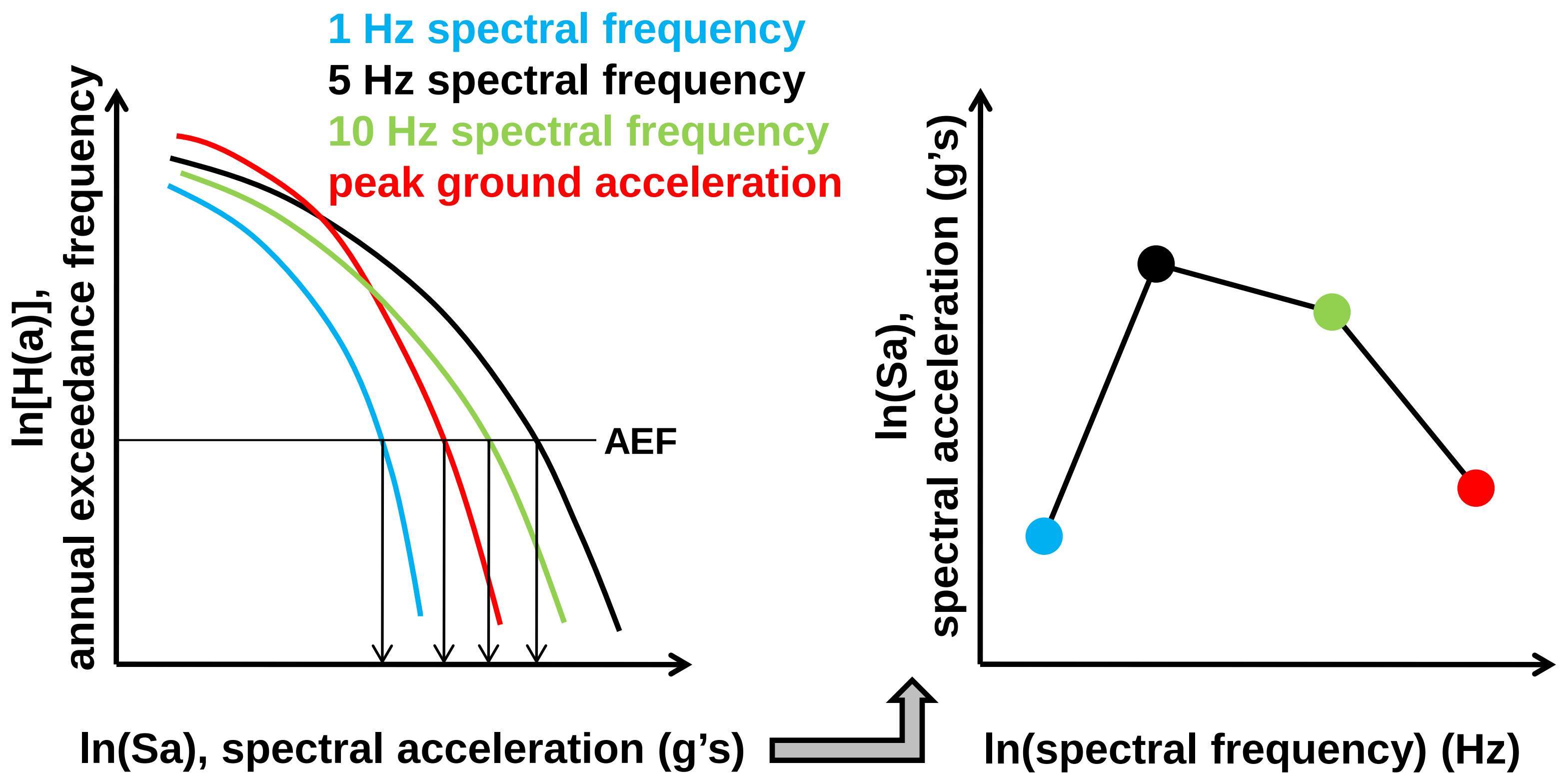
Uniform Hazard Spectra

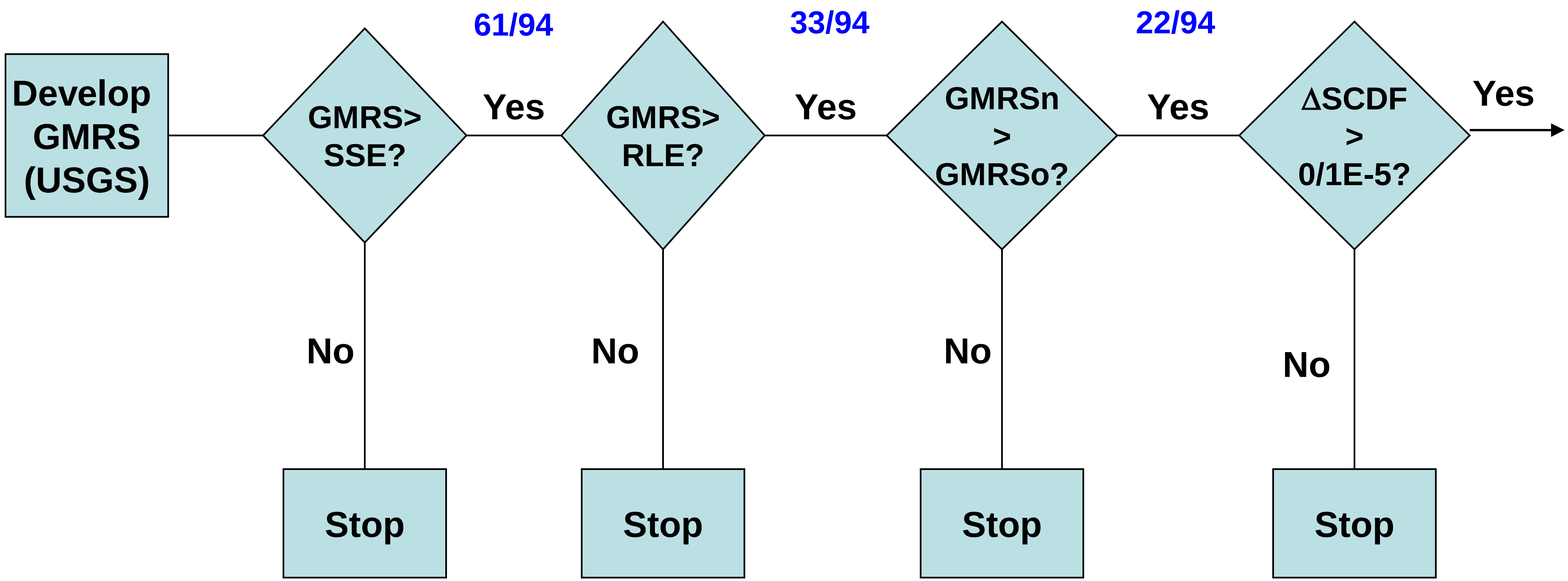


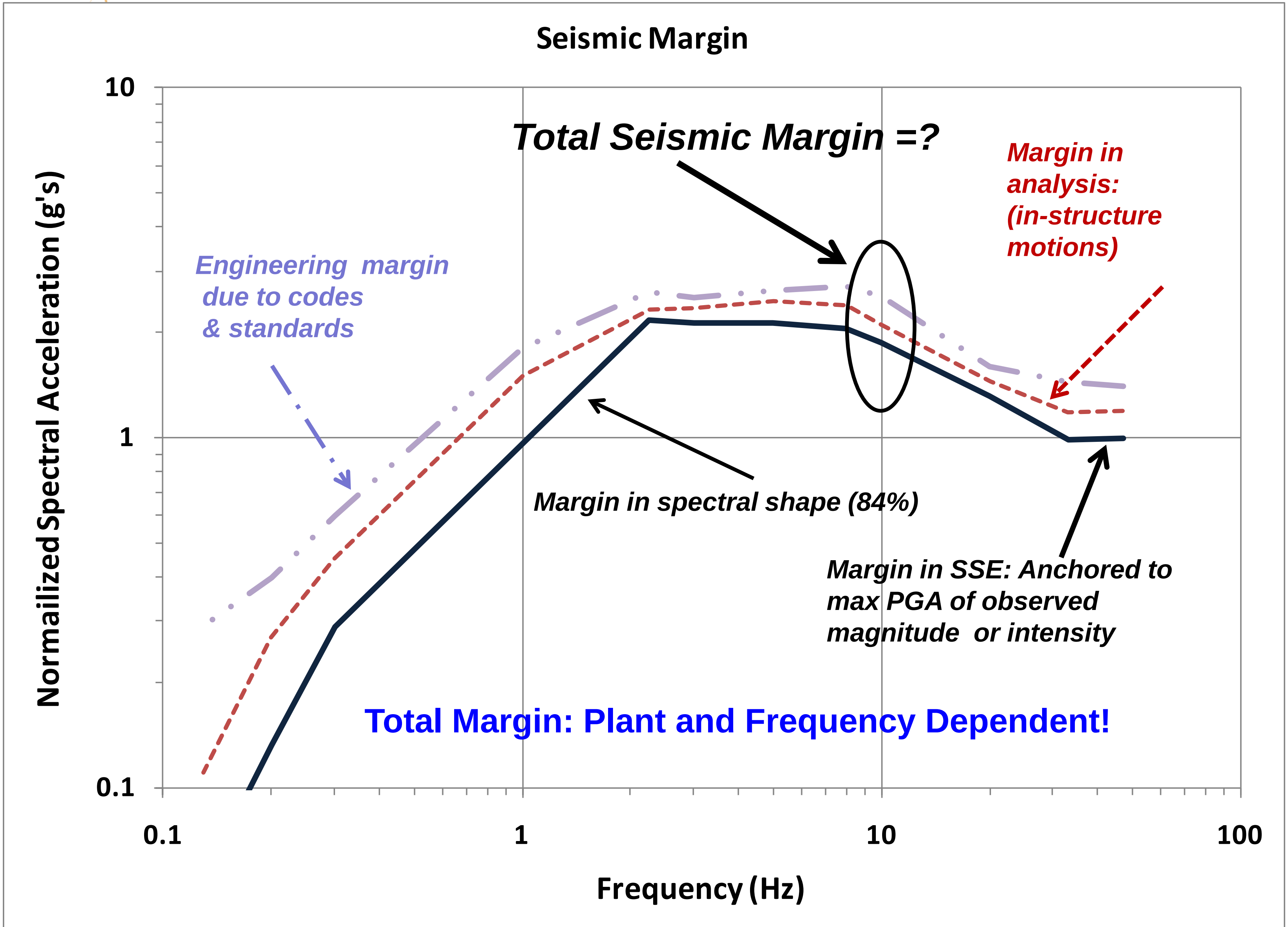
Individual Plant Examination of External Events (IPEEE) Program

- The IPEEE program also considered the implications of Beyond Design Basis Ground Motions.
- IPEEE used a review-level earthquake (RLE) whose spectra exceeded/equaled the SSE and demonstrated plant safety either with low core damage frequency (via SPRA: ~30% CEUS plants) or high seismic margin (via SMA: ~70% CEUS plants).
- The emphasis was on developing risk insights.
- Seismic hazard curves from EPRI and LLNL used.

Hazard/Risk Evaluation Process

Per 1.208	Test vs. Design Basis	Test vs. Previous Review	Test vs. Uncertainty in Hazard	Test vs. MD 6.4 Risk Metric





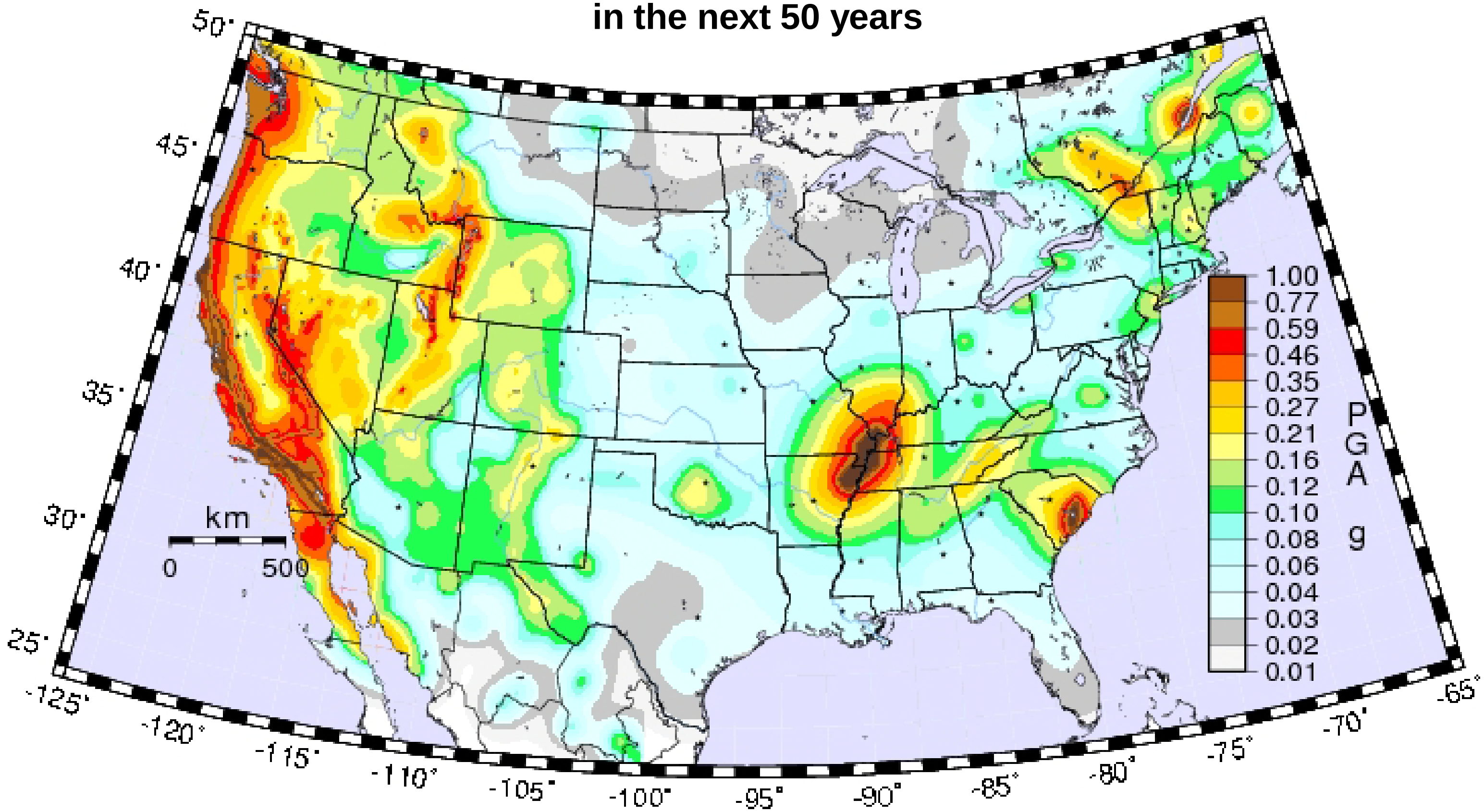
Seismic Margin
Total Seismic Margin =?
Margin in analysis: (in-structure motions)
Engineering margin due to codes & standards
Margin in spectral shape (84%)
Margin in SSE: Anchored to max PGA of observed magnitude or intensity
Total Margin: Plant and Frequency Dependent!
Normalized Spectral Acceleration (g's)
Frequency (Hz)
10
1
0.1
0.1
1
10
100

Assessing the Implications of Increased Seismic Hazard

- Compare risk due to different seismic hazard curves:
  - IPEEE-era curves:
    - 1989: EPRI/SOG (EPRI NP-6395) – many plants
    - 1994: LLNL (NUREG-1488) – all plants
  - Recent curves:
    - 2000s: ESP and COL applications for co-located plants – few plants
    - 2000s: EPRI curves – proprietary information for six sites provided under NRC/EPRI Memorandum of Understanding for collaborative seismic research
    - 2008: USGS – all plants
- When performing a Safety/Risk Assessment of a generic issue, usually pick several "representative" plants for analysis. However, for GI-199, need to conduct analyses for each CEUS plant:
  - Nationwide variability of seismic hazards
  - Variability in plant-specific seismic fragilities

Seismic Hazard Variability

Peak ground acceleration (PGA) 2% probability of exceedance in the next 50 years



Source: earthquake.usgs.gov

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Crafting an Approach

- Available seismic fragility information from IPEEEs:
  - 30% based on Level 1 seismic PRAs (SPRAs)
  - 70% based on seismic margins analysis (SMAs)
  - Limited information on seismic containment performance
  - Plants have been modified since the IPEEEs, but the impact of these modifications on seismic fragility is not well understood
  - IPEEEs completed before consensus standards on PRA quality were developed; no peer review or in-depth staff review.
- Prohibitive effort to develop SPRAs for all plants.
- The approach:
  - For each CEUS plant,
  - Combine mean seismic hazard curves (EPRI/SOG, LLNL, and USGS)
  - With the mean plant-level fragility curve
  - Developed from IPEEE information to
  - Estimate SCDF.

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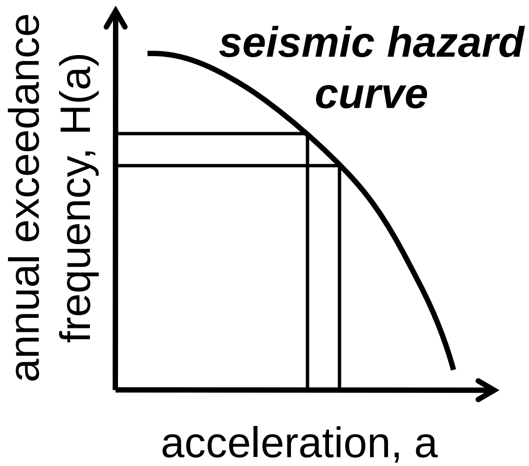
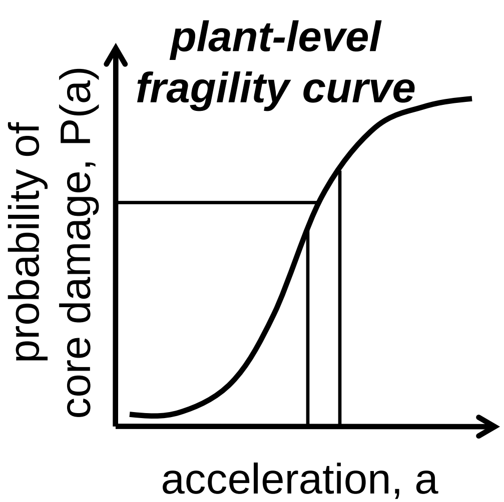
Computing SCDF





Over a small range of accelerations, the SCDF contribution is the product of:

- The frequency of earthquakes with accelerations in the range, and
- The probability of core damage given acceleration within the range

Add up the contributions over all accelerations.

$$SCDF = \int_0^{\infty} P(a)\left(-\frac{dH(a)}{da}\right)da$$

$$= \int_0^{\infty} H(a)\frac{dP(a)}{da}da$$

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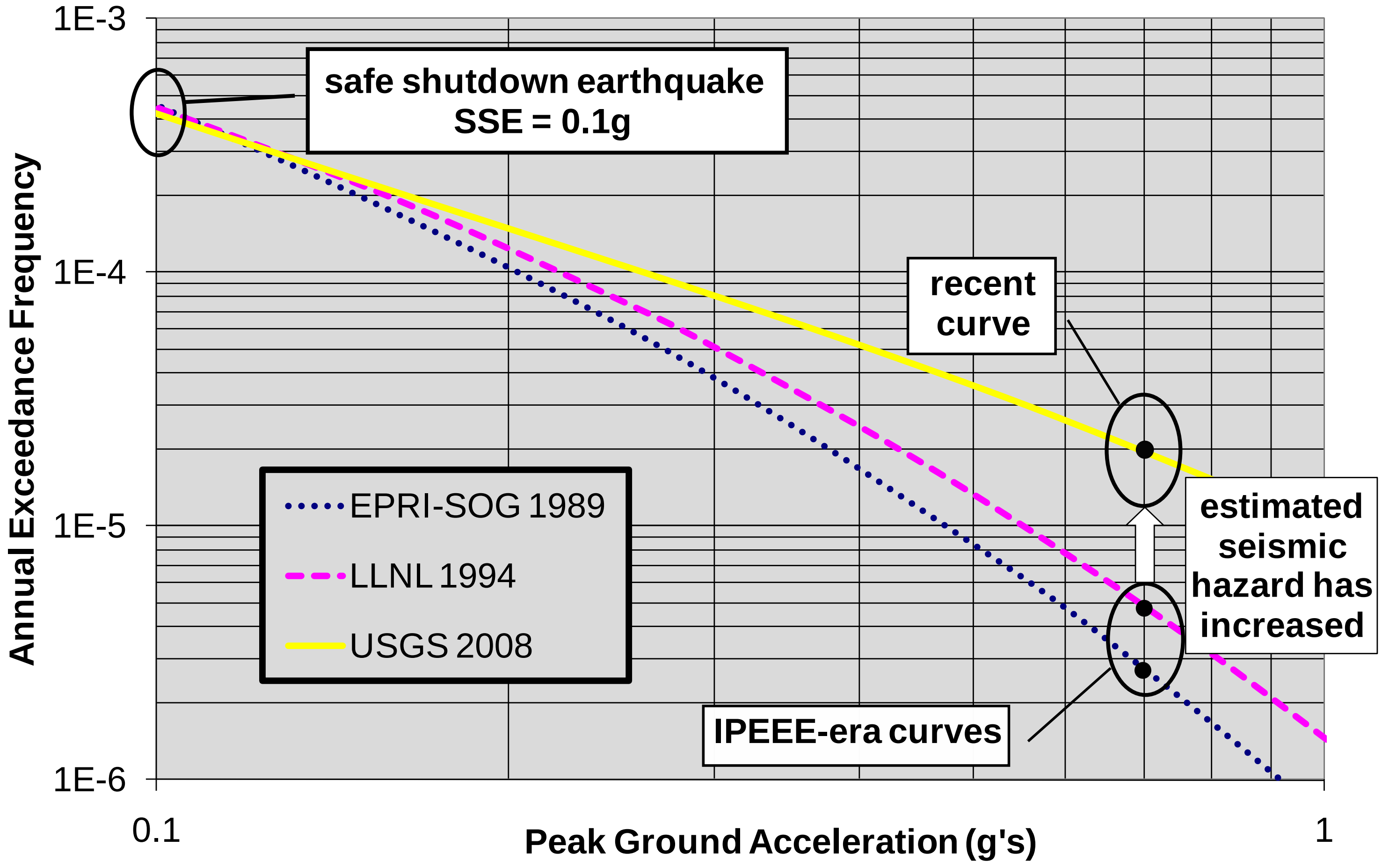
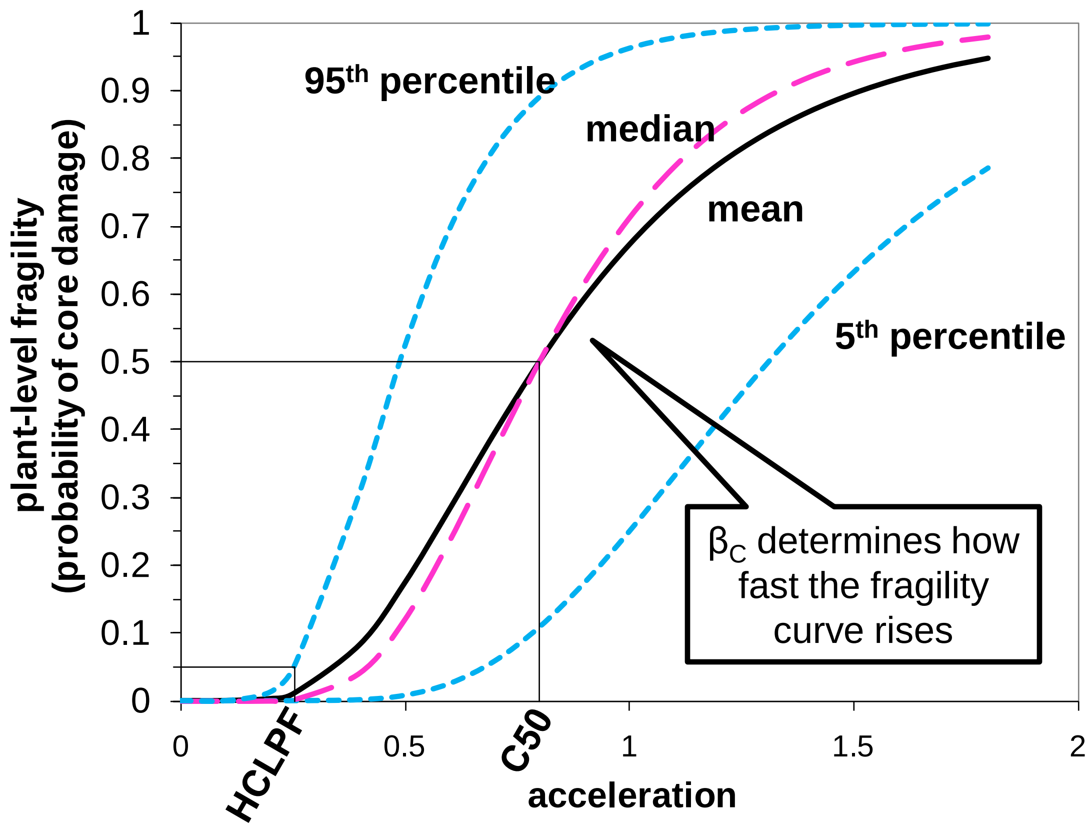
Example Seismic Hazard Curves



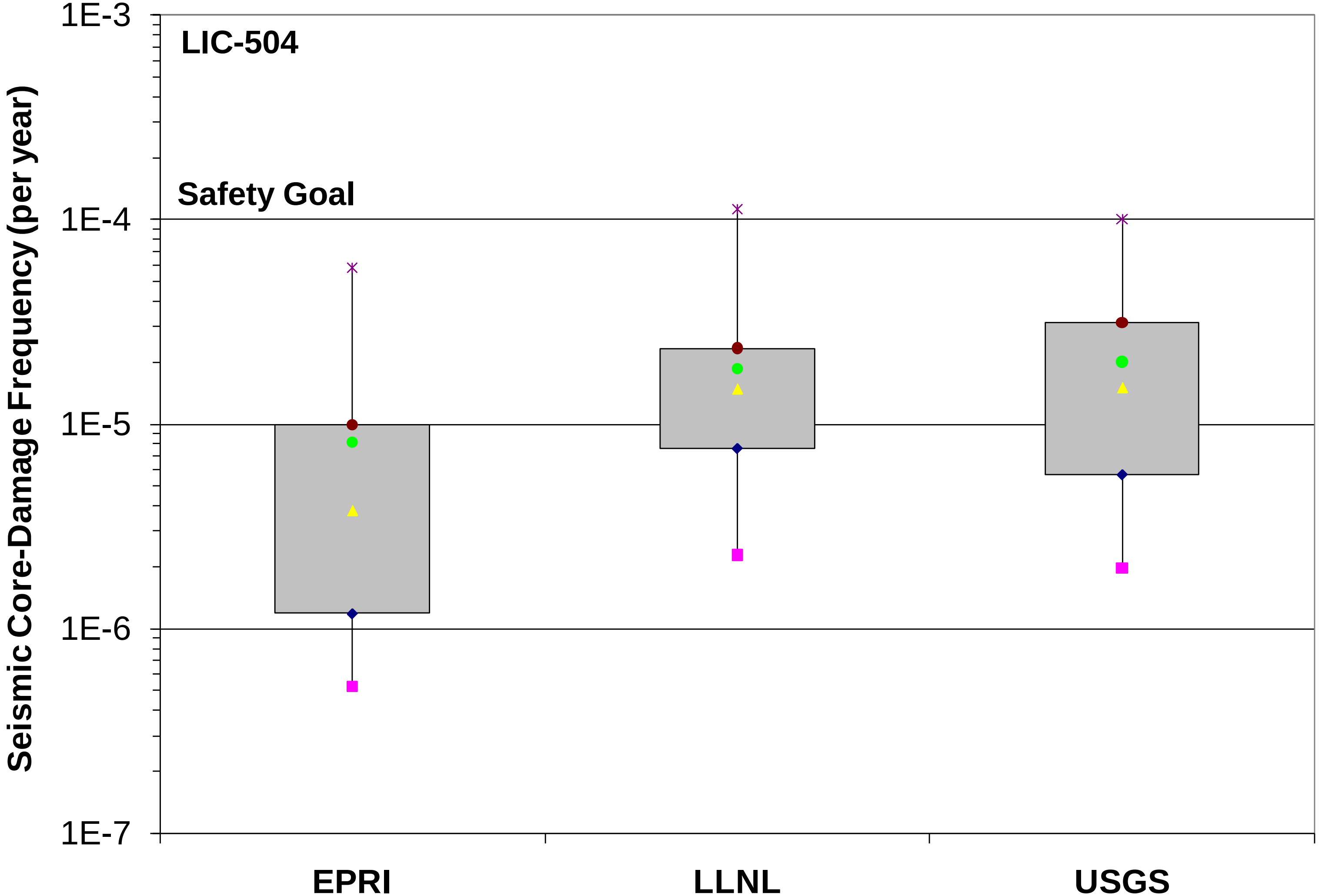
Plant-Level Seismic Fragility Curves

- Determined by SPRA
- Log-normal shape with two parameters:
  - C_{50} is the median seismic capacity
  - β_C is the composite logarithmic standard deviation
- Can be estimated from SMA: The plant-level HCLPF approximately corresponds to a conditional core-damage probability of 0.01



PGA, acceleration for a specific spectral frequency (e.g., 10 Hz), or acceleration over a range of spectral frequencies (e.g., 3-8Hz)

Fleetwide SCDF Variability



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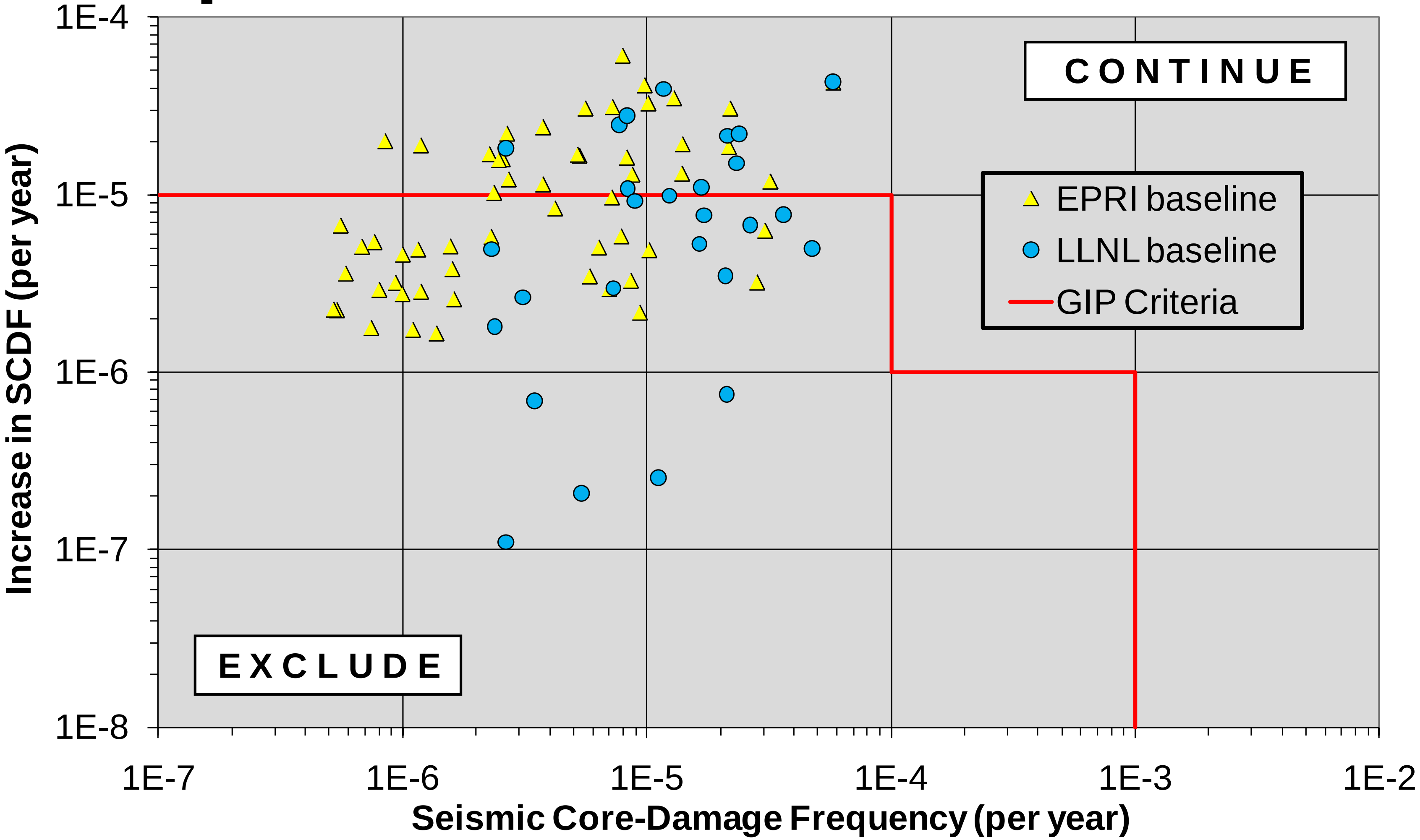
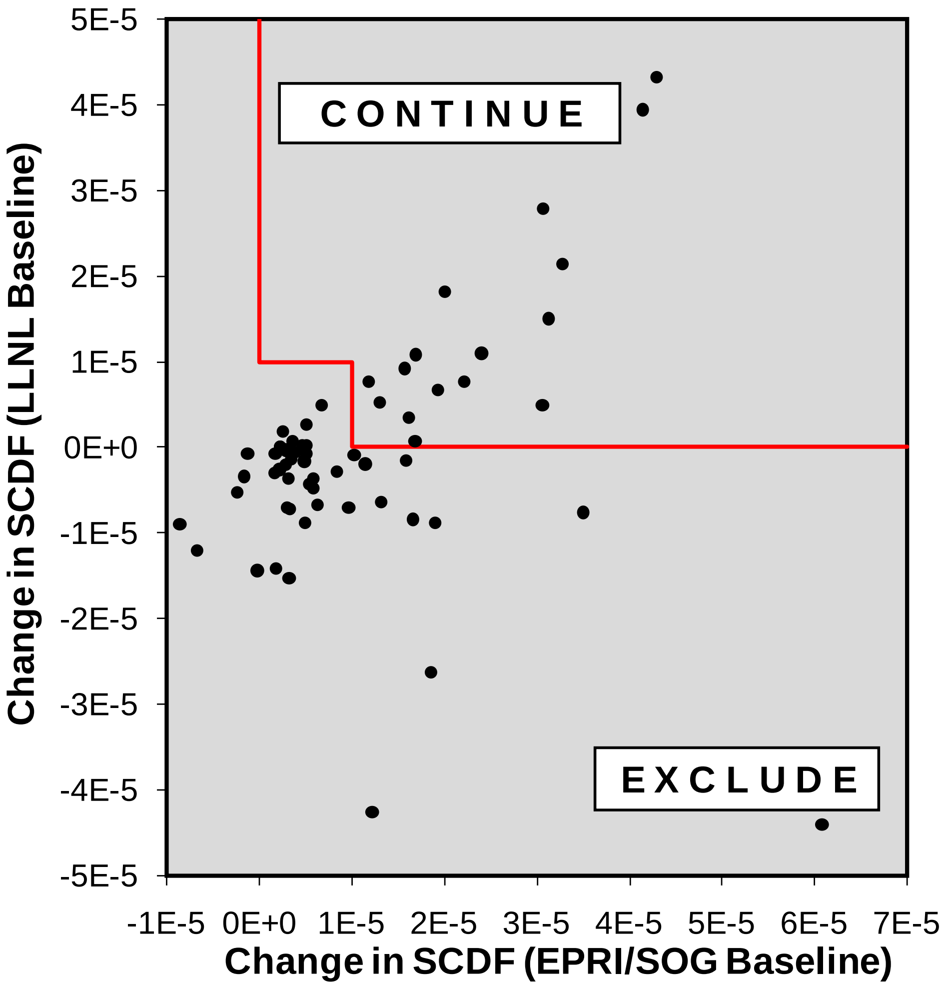
Comparison to GIP Criteria



Delta-Delta Plot



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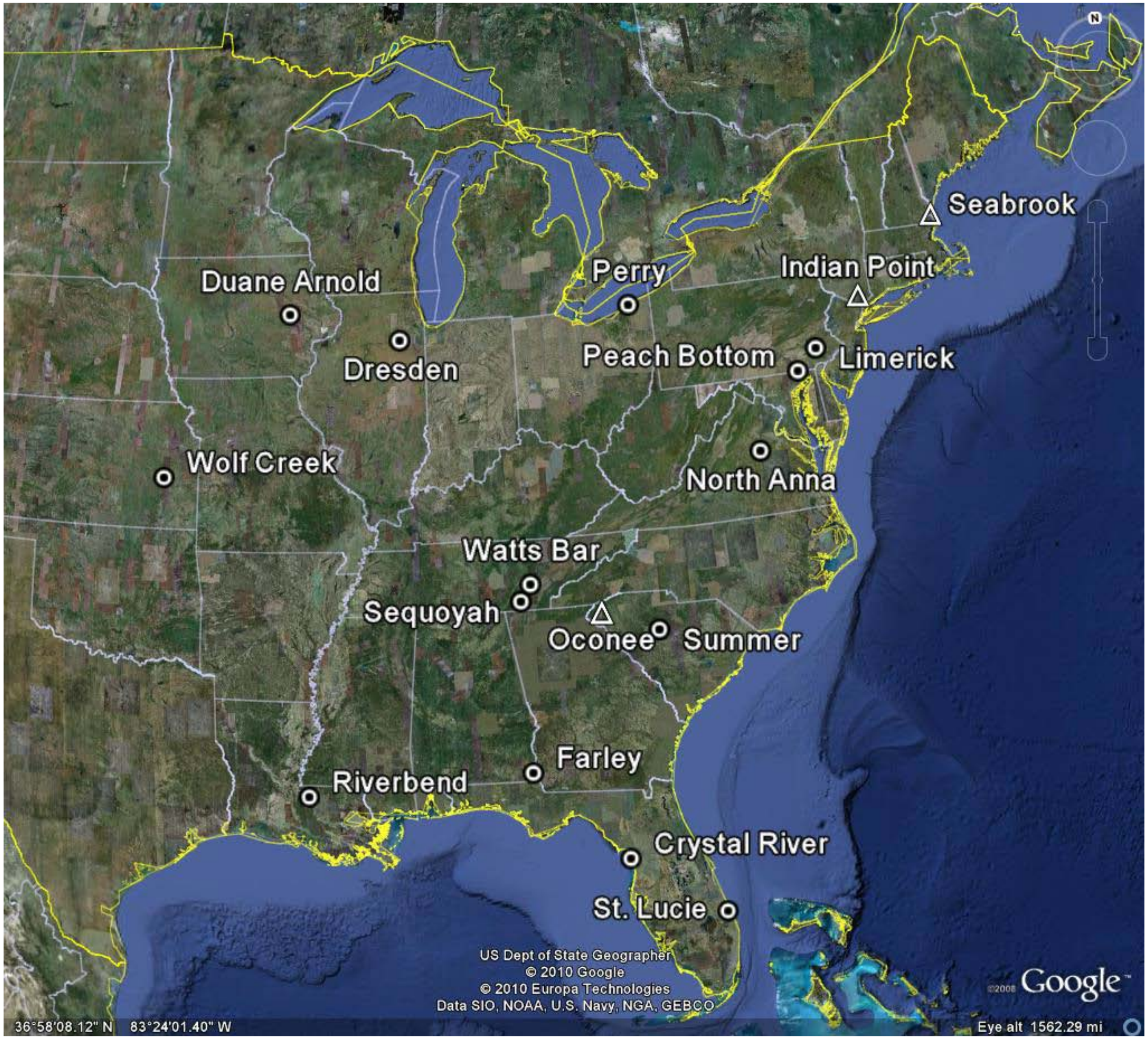

Plants in the "Continue" Zone

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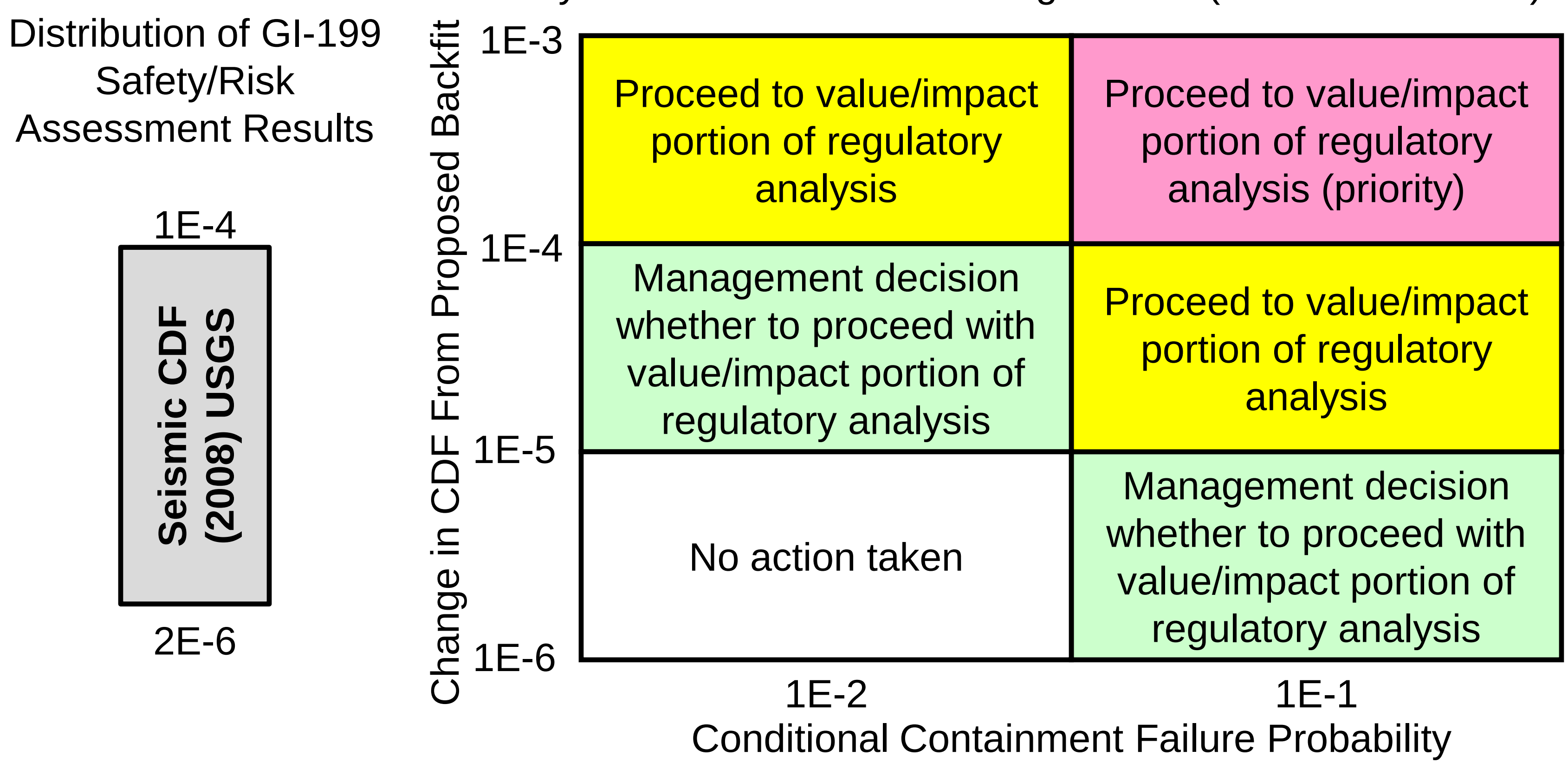
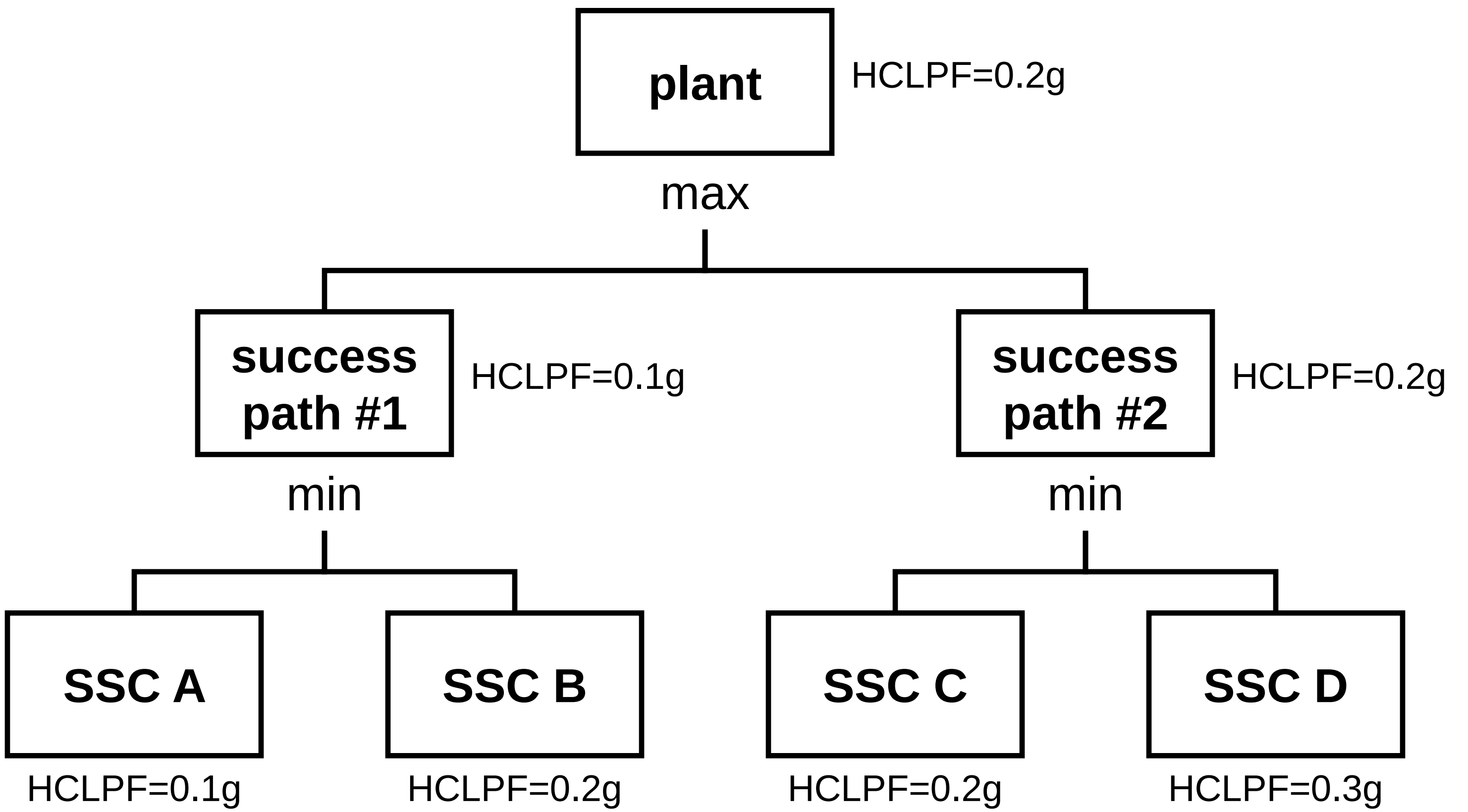
Do We Need to Consider Backfits?

Cost-Justified Backfits That
Provide Substantial Safety Enhancements
Safety Goal Evaluation Screening Criteria (NUREG/BR-0058)



Improving the Plant-Level HCLPF



Which SSC should be improved to increase the plant-level HCLPF?

Needed for GI-199 Regulatory Analysis

- Updated site specific hazard curves
- Frequency dependent, site specific amplification functions
- Plant level fragility information
- Plant specific contributors to seismic risk
  - Can be produced for plants with seismic PRA
  - Will need method developed for plants with SMA
- Need repeatable approach for evaluating new seismic hazard information and future updates

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Path Forward

- NRR lead with RES support
  - Issue has transitioned from the GI Program to Regulatory Office Implementation
  - Issued Information Notice 2010-018 and 2010-019 to inform licensees of the GI-199 Safety/Risk Assessment results
  - Develop a generic communication to request needed data
  - RES will work with EPRI on method for plants that used Seismic Margins Analysis (SMA)
  - RES will develop inputs for GI-199 regulatory analysis under a user need request

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GI-199 Key Points

- Operating power plants are safe
- Seismic hazard estimates have increased at some sites
- Assessment of GI-199 will continue
  - Information is needed to perform regulatory assessments
  - NRC will request the needed information

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Thanks

QUESTIONS?

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Backup Slides

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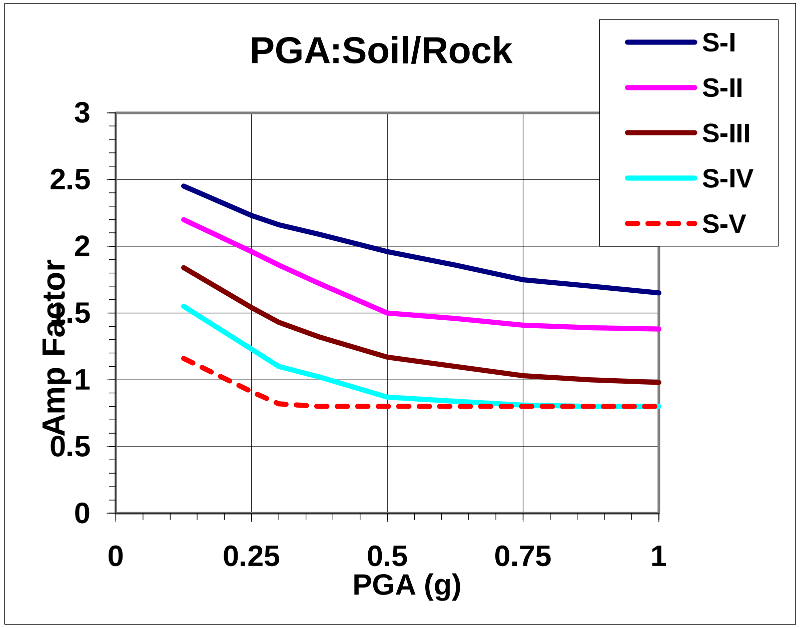
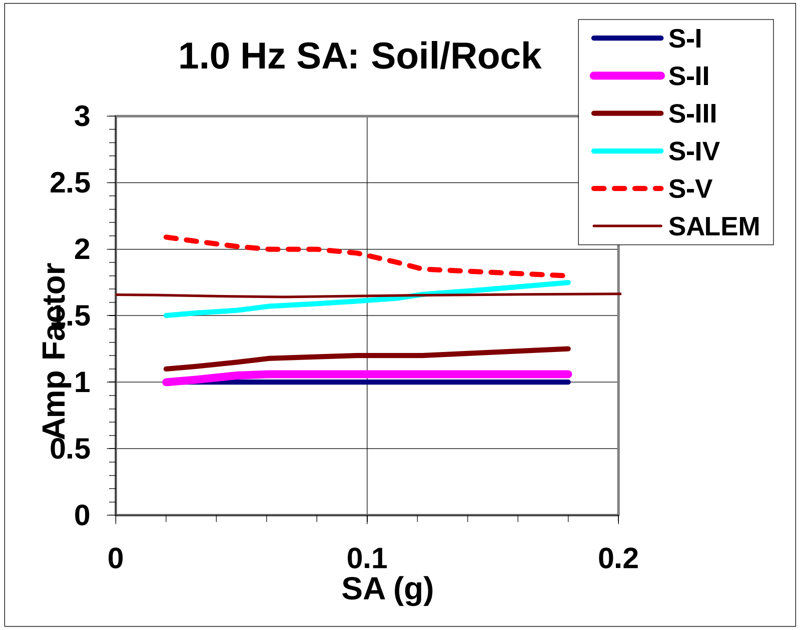
Acronyms and Initialisms

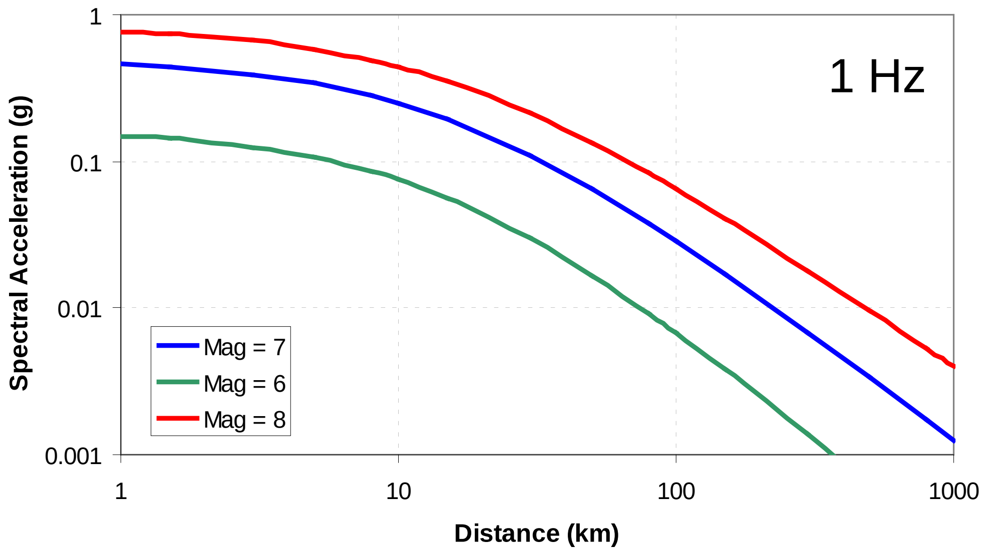
ANS	American Nuclear Society
ANSI	American National Standards Institute
CAV	cumulative absolute velocity
CDF	core-damage frequency
CEUS	Central and Eastern United States
EPRI	Electric Power Research Institute
ESP	early site permit
GI	Generic Issue
GMRS	ground motion response spectrum
HCLPF	high confidence of low probability of failure
IPEEE	Individual Plant Examination of External Events
LLNL	Lawrence Livermore National laboratory
MD	Management Directive
MOU	memorandum of understanding
NRR	Office of Nuclear Reactor Regulation
PGA	peak ground acceleration
RES	Office of Nuclear Regulatory Research
RG	regulatory guide
SCDF	seismic core-damage frequency
SMA	seismic margins analysis
SPRA	seismic probabilistic risk assessment
SSE	safe shutdown earthquake
USGS	U.S. Geological Survey

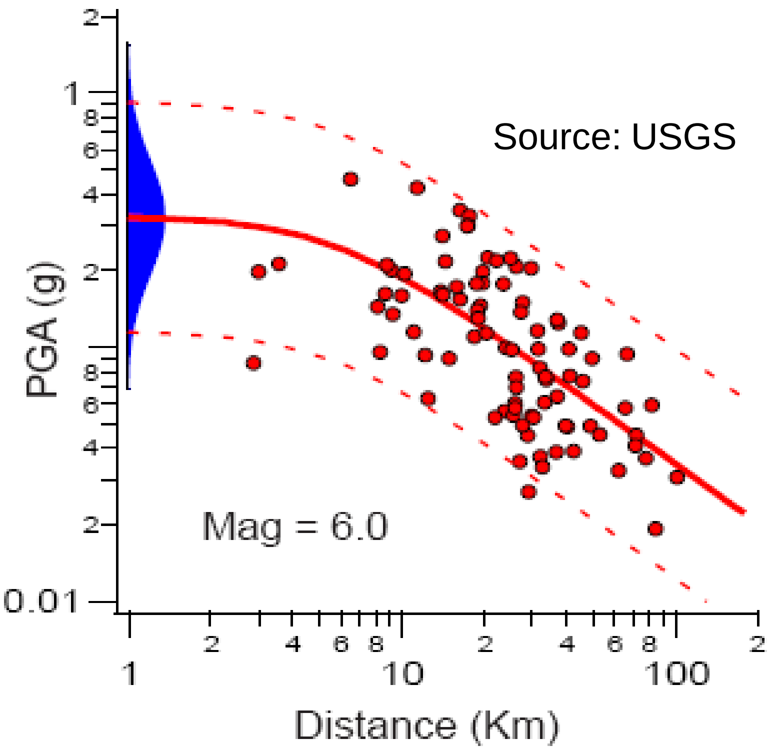
Example Soil Amplification Functions





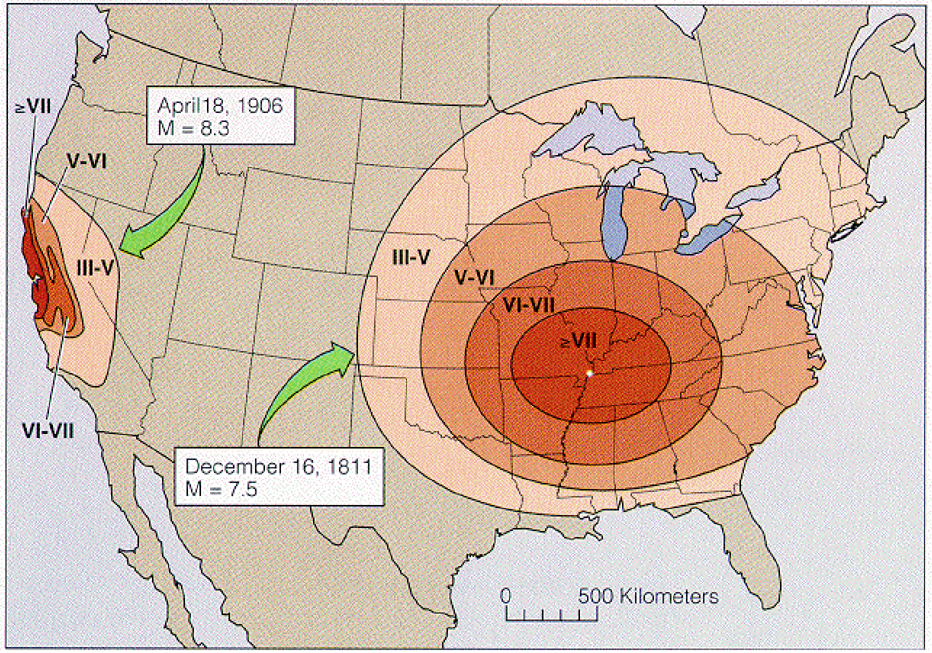
Seismic Wave Amplitudes vs. Distance





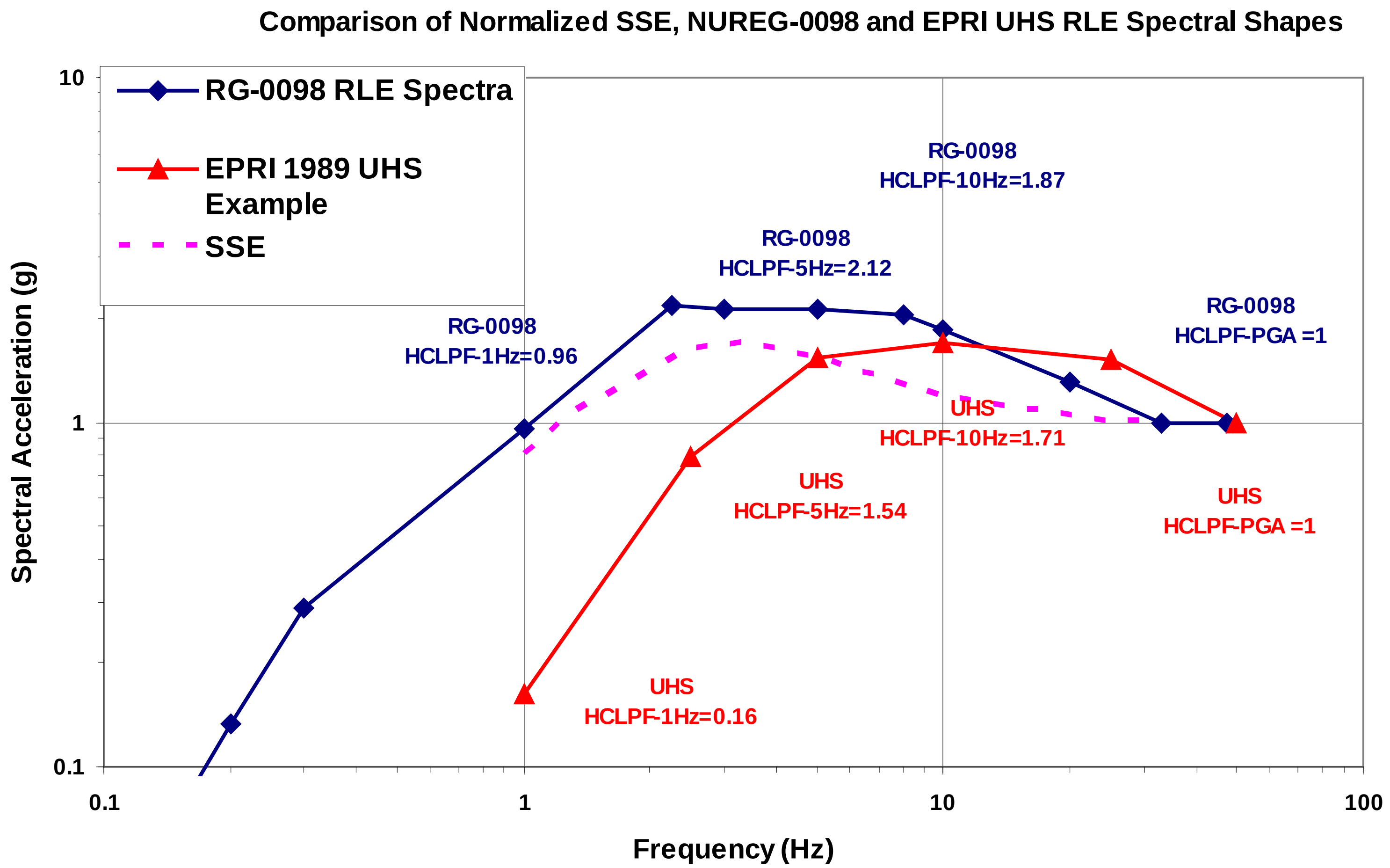
Ground Motion Prediction Models

- **Seismic attenuation is region specific**



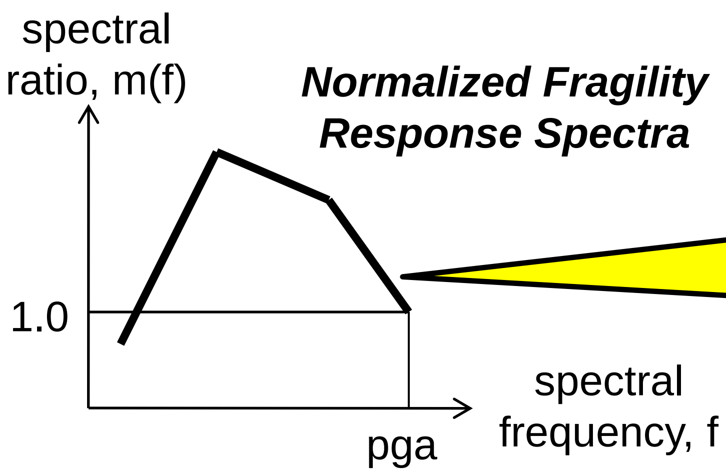
- **Different ground motion prediction models are used for western and eastern United States**

Response Spectral Shape



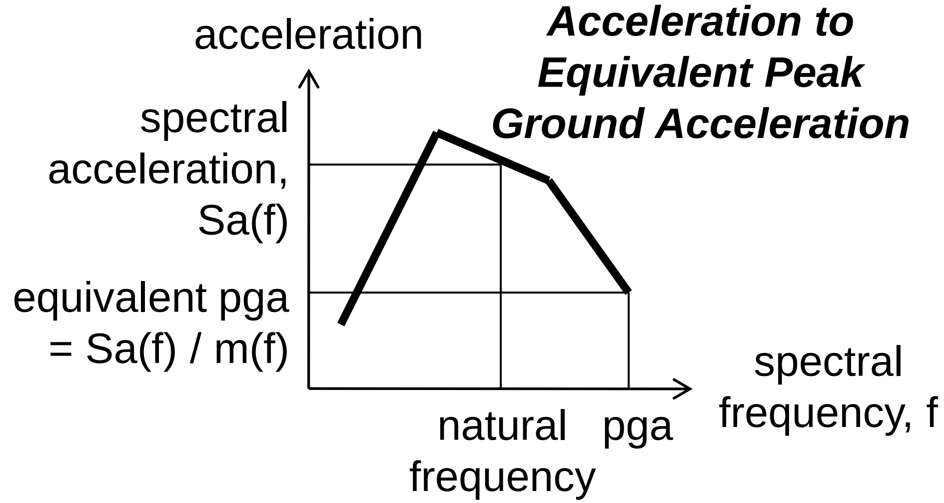
Spectral Ratios

Normalized Fragility Response Spectra

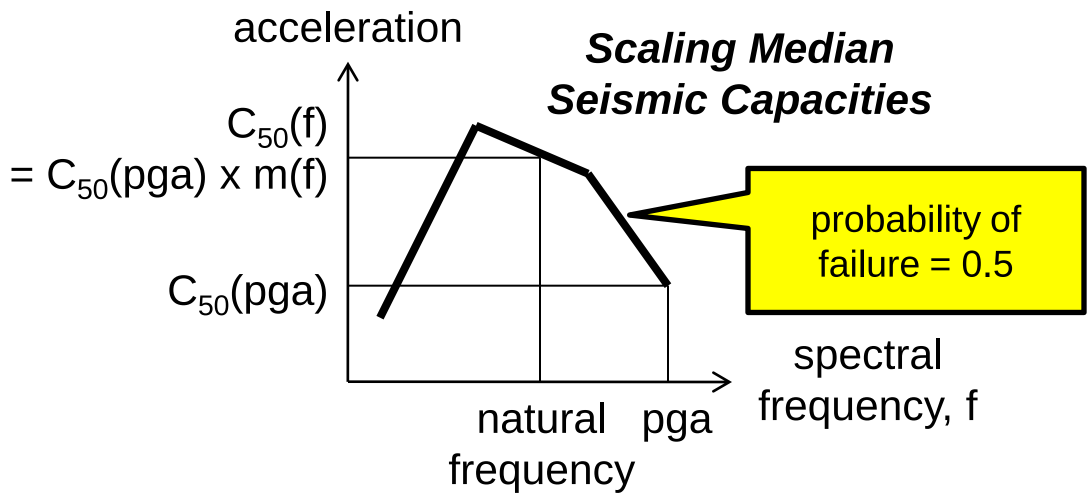


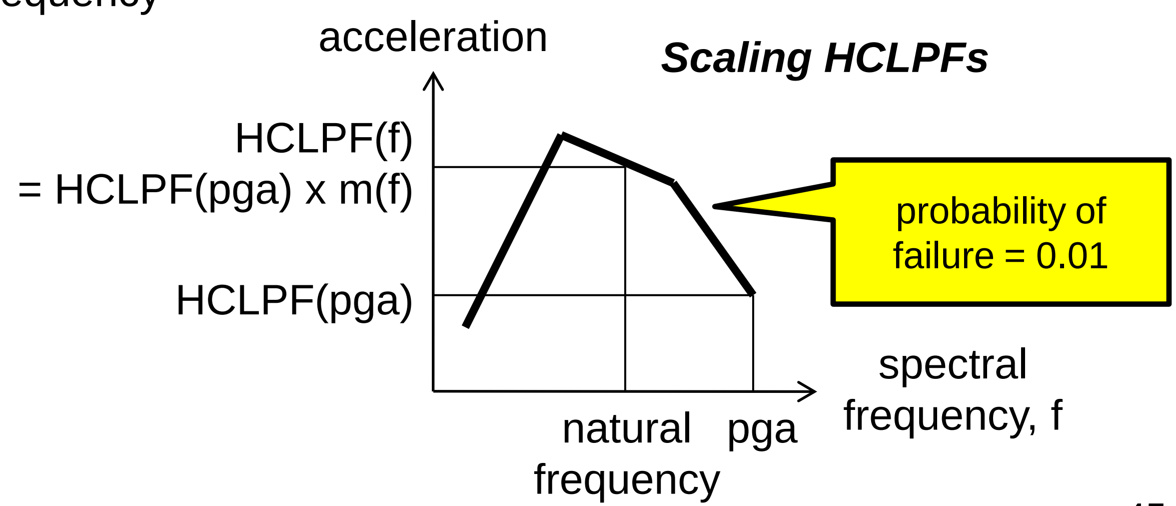
Based on:
- Design-basis shape,
- Other standardized shape, or
- UHS at specified AEF

Converting Spectral Acceleration to Equivalent Peak Ground Acceleration

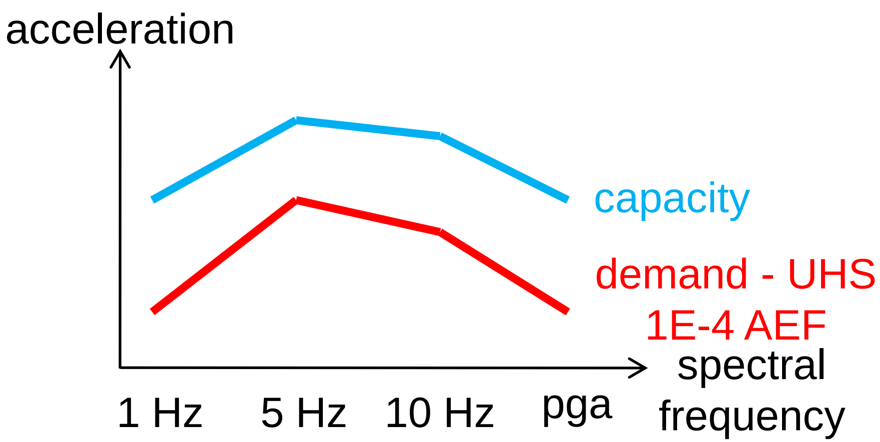


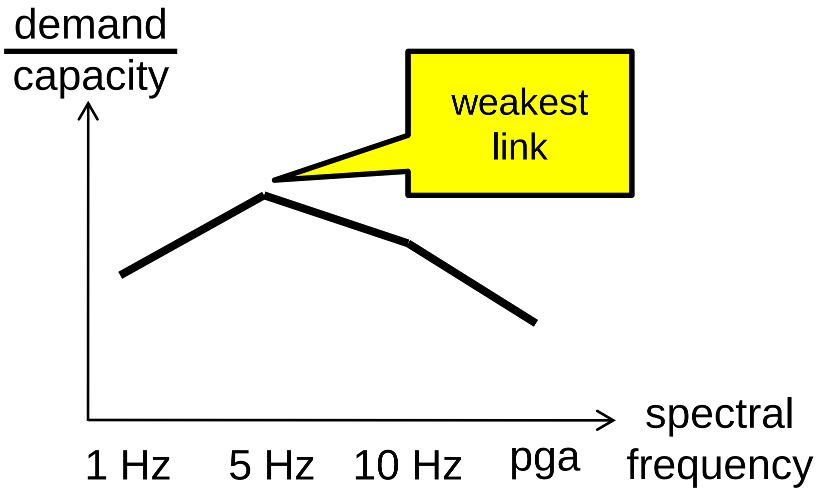
Spectral Fragility

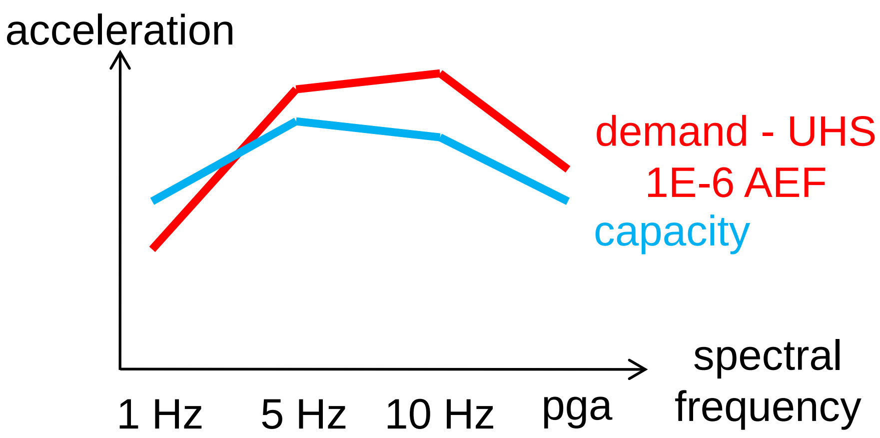


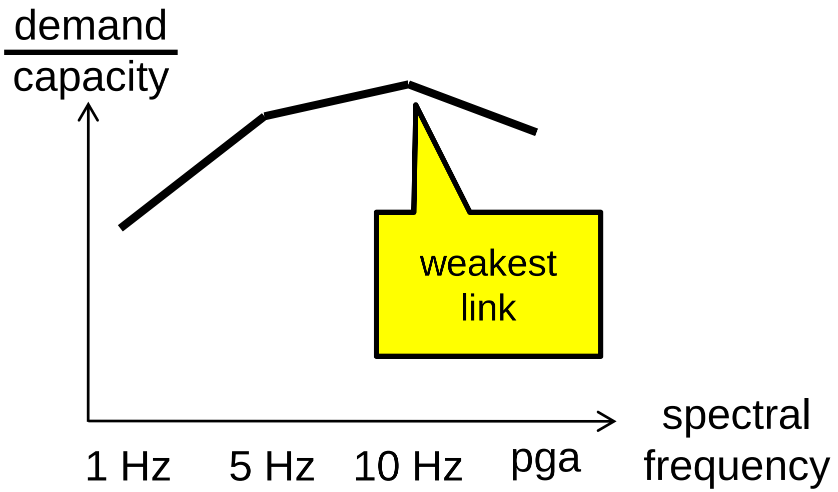


The Weakest Link Model









Algorithm for the Weakest Link Model

- Pick a value of peak ground acceleration (pga).
- Find the corresponding spectral accelerations from the spectral seismic hazard curves (i.e., find the UHS for the given pga).
- For each spectral frequency, compute the ratio of the spectral acceleration (demand) to the median seismic capacity at that spectral frequency.
- Over all spectral frequencies, find the maximum ratio of spectral acceleration to the median seismic capacity (i.e., the weakest link).
- Compute the probability of core-damage

RESULTS

- For each CEUS plant, we determined 8 SCDFs for each hazard curve:
  - SCDF(pga)
  - SCDF(1 Hz), SCDF(5 Hz), and SCDF(10 Hz)
  - Simple average of SCDF(pga), SCDF(1 Hz), SCDF(5 Hz), and SCDF(10 Hz)
  - IPEEE-weighted average: 1/7th of SCDF(pga) plus 2/7th each of SCDF(1 Hz), SCDF(5 Hz), and SCDF(10 Hz)
  - The maximum of SCDF(pga), SCDF(1 Hz), SCDF(5 Hz), and SCDF(10 Hz)
  - The weakest link model
- Implemented in MS Excel® with Visual Basic® macros.
- Calculation time of the entire workbook is several minutes.

The Generic Issues Program (GIP)

- Description
- Purpose
- Resources
  (http://www.internal.nrc.gov/RES/projects/GIP/index.html)
  (http://www.nrc.gov/about-nrc/regulatory/gen-issues.html)
- Improvements

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Protecting People and the Environment

The Seven GIP Criteria

1) Significant implications for public health and safety
2) Applies to two or more facilities
3) Not readily addressable through other established regulatory processes
4) Can be resolved by regulation, policy, or guidance
5) Risk or safety significance can be adequately determined or estimated
6) Well defined, discrete, technical
7) May involve review, analysis, or action by the licensee