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TRANSCRIPT OF PROCEEDINGS

Public Meeting

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## 1 PROCEEDINGS

2 MR. FARNHOLTZ: Okay. Welcome back from lunch. I hope  
3 everybody had a good one. My name is Tom Farnholtz. I'm a branch chief in the  
4 NRC Region 4 office in Texas, and I'm here to introduce our next session of  
5 speakers for the Session No. 3. Probabilistic Seismic Hazard Assessment is the  
6 name of this session. The speaker is Annie Kammerer is a senior seismologist  
7 and earthquake engineer in the Office of Nuclear Regulatory Research at the  
8 NRC office and headquarters in Maryland. She coordinates and manages the  
9 Seismic Research Program, overseeing research on topics such as a seismic  
10 hazardous assessment and seismic risk assessment for nuclear facilities.

11 And then Mark Petersen is the chief of the U.S. Nuclear Seismic  
12 Hazard Mapping Project of the U.S. Geological Survey in Golden, Colorado. He  
13 also serves as a national coordinator for the USGS Earthquake Hazard Program.  
14 One thing of note, you'll notice when Mark does his talk and his slides, you'll  
15 notice the slides are not in the package, and that's because we didn't get those in  
16 time to include those in the printing order. But they will be posted on the public  
17 website following the completion of this workshop. So four following along on the  
18 slides and can't find them that's the reason. Thank you. And Annie.

19 DR. KAMMERER: Thank You. I just wanted to clarify really quickly  
20 that Mark is the chief of the National Seismic Hazard mapping program, not the  
21 nuclear seismic --

22 MR. FARNHOLTZ: My apologies.

23 DR. KAMMERER: [laughs] Just for clarification purposes. Well,

1 hello. Many of you I've seen before. Thank you very much for coming today.  
2 This is probably going to be very simple for many of you, especially given the fact  
3 that you've seen many elements of what I'm going to be talking about already,  
4 but my goal is really to make it simple enough that everybody leaves with an  
5 understanding of probabilistic seismic hazard assessment because it's something  
6 that we're going to see here related to the hazard assessment in the region over  
7 the next couple of years and so my goal is to really give everybody, especially  
8 the local participants in this workshop, an understanding of probabilistic seismic  
9 hazard assessment.

10           So we've seen, of course, that plate tectonics is the driving force of  
11 seismicity in this region. We've seen some really excellent presentations this  
12 morning related to that and that this region sits in a -- inner plate is its own --  
13 which is a very complex shear zone, so there's a lot going on, a lot of uncertainty.  
14 There's strike slip; there's thrust faulting. It's a very complex environment.

15           So some of the basic questions of seismic hazard assessment that  
16 we need to answer, there's really three fundamental questions. The first is how  
17 hard is the rock going to shake? What is our design or our review shaking going  
18 to be? How does the soil react? And I'm not going to talk about that in this talk.  
19 You saw Professor Moss discuss that earlier. And the basic question of  
20 earthquake engineering is, how do the structures systems and components  
21 react to that shaking and how do we design appropriately to make sure that the  
22 plant is sufficiently safe?

23           The important elements that determine shaking earthquake at a  
24 specific place are, of course, the magnitude of the earthquake, the distance from  
25 the fault to the site -- and we saw some discussion of that earlier -- and the

1 geology of the path from the point of rupture all the way to the sight. So how do  
2 we calculate how hard it's going to be, how hard the shaking is going to be?  
3 There's two basic approaches called deterministic seismic hazard assessment  
4 and probabilistic seismic hazard assessment, and so I'll go through the first and  
5 then the latter.

6           So deterministic assessments as we saw discussed earlier are  
7 worst-case scenario analysis that are based on known faults. We look at a single  
8 scenario, which we considered to be -- you heard the term "maximum credible  
9 earthquake" or "maximum vent on a particular fault." And for this we need two  
10 types of information. We need information about the fault, which we've seen  
11 called "seismic source characterization," and we need something called a  
12 "ground motion prediction equation." And some of you might recognize these as  
13 formerly being called attenuation relationships. Attenuation relationships are now  
14 called ground motion prediction equations, and basically what these equations  
15 are are statistical relationships that say for a certain magnitude earthquake this  
16 far from your sight of interest, what is the likely shaking that's going to occur? It's  
17 basically what tells you for a certain scenario event what's going to happen at  
18 your particular sight of interest.

19           Now, as we heard, there's a lot of challenges in determining what  
20 the worst case really is. There's -- sometimes there's uncertainty as to how large  
21 a fault really is or what magnitude it's capable of. Sometimes there's uncertainty  
22 in its exact location or is it going to rupture in the future exactly where it is in the  
23 fast and what we'll see is there uncertainty related to the ground motion  
24 prediction equations and so that's another question. So, in deterministic  
25 assessments what one tries to do is to deal with those types of uncertainties

1 through conservative assumptions. So, seismic source characterization, for this  
2 you require complete characterization of the faults that might produce that worst-  
3 case scenario.

4 Now, for probabilistic seismic hazard assessment, which I'll show in  
5 a minute, we need to characterize all possible sources that might impact the  
6 plant so we have to account for all the seismicity in the region, not just the  
7 particular scenario that we are considering. And as you saw in seismic source  
8 characterization, because of the complexity of the earth, particularly the  
9 complexity of the seismic zone such as we're in and the nature of natural  
10 variability, it's very, very important to use multiple sources of data to determine  
11 that characterization. We saw many different types of sources of data today, and  
12 all of those are critically important for creating a picture.

13 So the work that we saw earlier in the last session is very, very  
14 important for trying to characterize in certain in this region so just as a reminder,  
15 some of the types of data that we are looking at seismicity, which of course, is  
16 really one of our fundamental pieces of data because those are earthquakes.  
17 That's what we're considering. So we saw Dr. Hardebeck discussing how some  
18 of that's used. Topography, of course, we saw that in the landscape you see the  
19 effects of earthquake and that includes the multi-beam offshore work that's being  
20 done. Sub bottom profiling, which gets -- up there on the left, which goes to  
21 some information about where the faults may be. Geology, geomorphology, the  
22 magnetics gravity, we saw some geodetic data with GPS, all of those pieces of  
23 data are pictures into this very complex earth, and we have to take them all  
24 together in order to try and develop our source characterization.

25 So ground motion prediction equations, as I mentioned, these are

1 basically statistically based relationships, here in the West, which take  
2 information from past events and develop a prediction of what we would see at a  
3 particular type. So these are recordings from the magnitude 6 Parkfield,  
4 California earthquake; we saw some information about this earlier. And one  
5 thing that you can see is that there's scatter in the data, so as you can imagine,  
6 not every time you are, say, 10 kilometers from a magnitude seven earthquake  
7 are you going to have the exact same shaking at your site. There's natural  
8 variability in the earth; there's natural variability in the way that the fault ruptures.  
9 And so for that reason, there is what we call aleatory uncertainty or aleatory  
10 variability, natural variability in the process of the earth that we need to account  
11 for. So the line in the middle is the ground motion prediction equation that was  
12 developed by Boore [spelled phonetically] in '97.

13           So, one of the things that's important is to look at the range of that  
14 variability and our ground motion prediction equations. Now, I mentioned in  
15 deterministic analysis, we use what we consider conservative assumptions in our  
16 credible scenario. And so what we do and what we've probably seen, those of  
17 you who are familiar with some of the local information is we use an 85th  
18 percentile ground motion. And so if you were wondering on some of the plots  
19 that some of you have seen before, what that 80, 84th percentile means, it's  
20 basically that the upper bound of that blue band, which accounts for all of the  
21 uncertainty in the data. So these basically show the plus and minus one  
22 standard deviation along with the meeting ground motion. Now for, probabilistic  
23 seismic hazard assessment we look not at a single value but we actually  
24 integrate over all of those ground motions and it's a very important element in  
25 characterizing the uncertainty.

1           Okay, so moving to probabilistic seismic hazard assessment. For  
2 this we need to consider all sources that might impact a site and that includes  
3 both faults that we are aware of and back ground seismicity. You heard several  
4 times earlier that earthquakes occur that all not necessarily directly tied to a fault.  
5 We can't tie them to a specific known feature. In probabilistic seismic hazard  
6 assessments you have to account for both. So you take the recorded seismicity;  
7 you take the energy that's coming in out of a region. You saw Tim Dawson  
8 showed a plot of a scale saying all the energy going in has to be accounted for  
9 and all the energy going out and see that's how we make sure sin probabilistic  
10 seismic hazard assessment that we are incorporating all of that potential energy.

11           An important element of PSHA is that it considers the probability or  
12 likelihood of different events over time, which is different from deterministic  
13 assessments. And they also have to account for, what we call model uncertainty  
14 or epistemic uncertainty. There was -- in Tim Dawson's talk he was talking about  
15 how slip rates are not necessarily well-known so we have to account for the  
16 uncertainty in various parameters that go into the assessment. Now the NRC  
17 currently uses a probabilistic approach which considers the -- an annual  
18 probability, a ground motion, a 10 to the minus four, so that's basically a one in  
19 10,000 ground motion for the assessment of new facilities.

20           So you've seen that something like this before a couple of times.  
21 This is a logic tree, and this is how we account for the uncertainty in our seismic  
22 source characterization and also the ground motion prediction equation models  
23 in a probabilistic assessment. And so as we address some of the questions that  
24 are coming out from the research that's happening at the USGS that we saw  
25 earlier in CGS [spelled phonetically], this is a way to account for the uncertainty



1 that we are not quite sure if, for example, the exact location of a fault, or how  
2 long it is, or what its maximum magnitude is. This is the tool that we use to  
3 transparently show the uncertainty in the source characterization model that will  
4 be developed.

5           So just very quickly to talk about what it actually is, what are the  
6 components? I think I lost the mouse; there we go. Okay. So the first step, so  
7 just -- the PSHA consider the effects of all possible earthquake scenarios and the  
8 uncertainty in the different input parameters. It takes each scenario and says,  
9 okay, what is that scenario mean for my particular site? And these are not just  
10 maximum scenarios; these are also smaller events on the fault. For each  
11 scenario, okay, what will happen at my particular site and what is the likelihood of  
12 event of that actually happening? And all of these are combined together in a  
13 probabilistic framework.

14           So the first thing that we need to do is develop our seismotectonic  
15 model our seismic source characterization that it counts for all of the faults and  
16 all of the back ground seismicity and the uncertainty in all of those. Now, for  
17 each source we have to develop something called the recurrence model, which  
18 says that how often do earthquakes of different magnitudes occur? So we have  
19 the cumulative rate of earthquakes on that particular source verses magnitude.  
20 This tells us how likely any particular event is.

21           So taking all of those together to give us the whole suite of possible  
22 events and the likelihood that occur. We combine that with the ground motion  
23 prediction equations and the uncertainty in the ground motion prediction  
24 equations. Wrap that altogether and that gives us our ground motion hazard  
25 model. So what we're trying to do is very different from a deterministic analysis;

1 it's looking at all possible events.

2                   Now, what comes out of this is something called a “uniform hazard  
3 response spectrum,” and it's called that because all of the points on this  
4 spectrum have uniform hazard. And some of you might have seen something  
5 that looks like this before but had no idea what it actually kind of meant other  
6 than it's a characterization of ground motion, so I'd like to go over it a little bit.  
7 And I want you to think back to your childhood of getting on a swing set. So kind  
8 of recall what it felt like: you get on and the swing is sitting there, and as you kick  
9 your legs, it moves and your swing goes higher and higher and higher. And if  
10 you recall, the way that that swing went back and forth it always had the same  
11 rhythm, and all that happened is you went higher and higher as you started  
12 moving faster and faster and faster. That was the natural frequency or the  
13 natural period of that particular swing, with of course, you being part of the  
14 system and if you recall when you got on something like a jungle gym like this the  
15 different swings had different natural frequency, and so some went really fast and  
16 some went really slow, but each particular swing had its own rhythm.

17                   Well, picture the swing set and an earthquake goes through it.  
18 First, it's sitting there, just sitting there quietly, not doing anything, and an  
19 earthquake comes through, the swings begin to move, and they are all moving in  
20 their own way because they all have their own natural frequency or natural  
21 period. The earthquake passes and the swings all come back to a static position.  
22 Well, at some point in that earthquake that swing, each swing, was moving its  
23 maximum extent. Either it was accelerating more than at any other time or its  
24 displacement was higher or its velocity was faster. So if you take that maximum  
25 response and you plot it against its natural frequency, what you end up with is

1 your response spectrum. So it's the response of a very simple system to that  
2 earthquake that's gone through.

3           So we use the same thing for different periods, different structures.  
4 One of the questions earlier that was asked was related to whether or not a small  
5 stout building verses a tall flexible building which one responds the most to  
6 share, and the answer is it depends on the frequency and the natural period of  
7 that particular structure. Well, this is really why, is because earthquakes are  
8 going to -- the frequency content of earthquakes are going to cause different  
9 simple systems to respond differently and also complex systems as well. So this  
10 response spectrum is how engineers receive information about how hard the  
11 ground shakes, and these are used for designer review. So these are -- this is  
12 the method of communication between the engineer and the seismologist. And  
13 so I would encourage those of you who can't remember what it feels like to sit on  
14 swing set to go find your inner child at some point over the next week and to try  
15 this little experiment, and if they only have one swing you should take one of the  
16 swing and throw it around the top and make it shorter so it will swing faster.

17           But so the uniform hazard response spectrum, with a little bit of  
18 modification is what's taken and turned into a safe shutdown earthquake, which  
19 we'll discuss a little bit later. So some of you seen this in terms of a response  
20 spectrum of different plans or comparisons and so that's what this actually  
21 means. Now, all of this is for a particular site, but the goal of something like the  
22 National Seismic Hazard Maps or the California Geologic Surveys portion of the  
23 California Hazard Map is to try and give a probabilistic hazard assessment for an  
24 enter large region which is a very challenging endeavor, and so next Mark  
25 Petersen is going to talk about how that's done for the enter U.S. and how the

1 data is used for that purpose and into the national building codes.

2 [applause]

3 MR. PETERSEN: So, again, I work for the U.S. Geological Survey,  
4 and we are responsible for making hazard maps for the entire United States, and  
5 these are used for a number of different applications. For example, we work with  
6 the building code communities to put these into the international building codes  
7 that are basis for most of the buildings that -- probably the building that we are in  
8 today. We have roads and bridges that are governed by these national maps,  
9 the railways. We have the insurance rates, so the insurance rate industry is  
10 using these maps to try and understand. So we try to really give a fair and  
11 balanced approach to assessing hazard, and typically, in the past, the building  
12 code community, in particular has really wanted to go to this probabilistic seismic  
13 hazard format because they can understand better. Even though it's a very  
14 difficult process to get your hands on but they can understand what the different  
15 uncertainty, how those uncertainties all fold into the hazard so you are not just  
16 designing for something that's an average kind of ground motion but you are  
17 designing for something that really is appropriate for the importance of the  
18 structure that you are looking at.

19 So today I want to just give you a favor for what we do in the USGS  
20 to try and develop these maps, and I wanted to start by showing you the process  
21 that we go through in developing these maps. To do this we know that there are  
22 -- there's a lot of good science that's done all over the world, and in particular, in  
23 the United States there are a lot of universities and private industry that is doing  
24 important research to us so we hold workshops. We hold four regional  
25 workshops around the United States to gather information on each of the

1 different areas and then we hold topical workshops to talk about the ground  
2 motion prediction equations like Annie just talked about. We have -- we work  
3 with the engineering communities so we talk with the user needs workshop  
4 where we discuss what kinds of parameters they are interested in understanding  
5 so that we can make these maps more useful to people. Do we have a pointer at  
6 all here?

7 FEMALE SPEAKER: No. You have to use the mouse.

8 MR. PETERSEN: Oh, okay. And in doing that we make draft map,  
9 and these draft maps all go out for public comment. So you can see there's a  
10 comment period here that went on for six months, and actually that says only two  
11 months but it was a lot longer, in 2007. We have an external review panel that  
12 reviews this. In cases where we don't -- where there's a lot of controversy I'm  
13 going to tell you about some ground motion prediction equations today that were  
14 a little bit controversial. We weren't sure if they real applied as well as we  
15 wanted so we wanted to get the -- we wanted to get the community together to  
16 try and assess whether the community felt that these ground motion prediction  
17 equations were appropriate for use in the National Seismic Hazard Maps. And  
18 then there's a lot of quality assurance that goes on, and we released the final  
19 maps back in January of 2008 and April 2008. And these now have been  
20 accepted into the NEHRP -- that should just be N-E-H-R-P -- 2009 version of the  
21 code the ASCE 7, 2010 and the IBC 2012 will then adopt these codes. So you  
22 can see it's a long process that we go through in order to get all this information  
23 together.

24 Now, for California, because California is such a complicated place,  
25 and also seismically --

1 [laughter]

2 -- we put a lot of effort into California, and we actually had a  
3 working group, a separate working group, that went forward with describing what  
4 are the different parameters that we should apply. So you can see the list of the  
5 different people that participated in it. We produced a Working Group on  
6 California Earthquake Probabilities that was also released about the same time  
7 as our National Seismic Hazard Maps in April of 2008. There was a separate  
8 review by both the National and the California Earthquake Prediction Evaluation  
9 Councils, so we try and put all the best minds on this to try and really give us the  
10 feedback so we can really have confidence that these maps are going to be used  
11 -- have the appropriate input in them for the use by the building codes and  
12 others.

13 For California we put a lot of effort into several different types of  
14 data. You can see down here at the bottom that we use a lot of geodetic data.  
15 We haven't always had that kind of data but we've been collecting geodetic data,  
16 GPS data, that will help us to analyze how fast the ground is straining. And so --  
17 or how fast it's moving. And so we use that data now. We put together strain  
18 map and we put in a lot of effort into trying to understand how that strain relates  
19 to earthquakes. We also put a lot of effort into mapping faults. And you can see  
20 here is a picture of a nice easy fault that you can map, but we have a lot of faults,  
21 more than 200 faults that are including in our model that have significant slip  
22 rates. So we have measuring how fast the ground is sliding past, -- slides past  
23 each other, the different slides of the fault to try to understand how many  
24 earthquakes we think can occur. The faster the slips, the more likely -- the more  
25 frequency of earthquakes we would expect to have on that structure.

1                   And we also -- I think there was some discussions in the last  
2 session about how we also need to determine different magnitudes and different  
3 sizes of earthquakes that can rupture on those faults. So we look a lot at  
4 different scenarios of how these things might rupture, and we do modeling of all  
5 the stresses to try and understand when a fault jumps to another strand and  
6 whether it jumps or not. And so, I think you have several discussions, probably --  
7 Tim Dawson has done a lot of paleoseismology where they dig a trench and try  
8 and understand from that data about how many earthquakes they can actually  
9 see in the trench to give us an idea of the frequency of those earthquakes. And  
10 then we have all the seismicity data from California that go back about 200 years  
11 or so and there's a lot of effort that goes into trying to assess what are the  
12 appropriate magnitudes in that catalog. Back in the 1800s there weren't as many  
13 people in California, and it was more difficult to assess the size of earthquakes  
14 so we have to go in and try to understand how big those earthquakes were so we  
15 can get an idea of how big the future earthquakes might be. And finally we make  
16 a composite forecast of the rate of earthquakes, which again was released to the  
17 public. So this is some of the information that actually goes into the California  
18 model itself.

19                   We also have spent a lot of effort recently putting together these  
20 strain maps. So on the left one over here, you can see the strain -- these are  
21 strain rate maps based on GPS measurements, many GPS measurements over  
22 the last 20 years or so, and you can see on the right panel some of the faults we  
23 have in our model that are color coded by the slip rates. You can see the San  
24 Andreas Fault coming up along through here and then the faults coming up along  
25 the coastal portion of central California. And you can see that same pattern is

1 observed when you just look at strain rates or the deformation rates in the Earth.  
2 And so we are trying again to put these altogether to try and understand how the  
3 activity rates of earthquakes from this geologic and geodetic data. And finally,  
4 again, we put a lot of effort into these catalogs, and you can see that along the  
5 can he say of California there has been a lot of large magnitude earthquakes.  
6 These are all magnitude 6 plus earthquakes in yellow, and you can see that there  
7 has been a number of these over the last couple hundred years. And, again, we  
8 spend a lot of effort in that.

9           So in the end we produce what's called an earthquake forecast.  
10 We can't predict earthquakes. We've been trying for a long time to try and really  
11 say yes an earthquake is going to occur here at this place in the next 10 years, or  
12 in the next year, or next week, but we can't do that yet. But what we can do is we  
13 can look at all this information and try and assess how often these earthquakes  
14 occur and then what the shaking will be related to that, and when we did this  
15 exercise for the entire portion of California, the 30 year probabilities of having  
16 earthquakes for California of magnitude greater than 6.7 -- and we chose a 6.7  
17 because that was the size of the Northridge Earthquake that caused a lot of  
18 damage down in the San Fernando Valley -- but the 30 year probability of having  
19 that is 99 percent. It's very likely if you go through almost any 30 year period in  
20 the past you would have seen a magnitude 6.7. We also do that for other sizes  
21 of earthquakes. There's a 94 percent chance that you'd have a magnitude  
22 greater than 7, a 46 percent chance that it would be greater than 7.5 and a four  
23 percent chance that you'd have a magnitude greater than 8. What's really in our  
24 model would be on the San Andreas Fault. This would be a major rupture, a  
25 1906 rupture that affected San Francisco or in 1857 rupture that was particularly



1 large. So these are the types of information -- and again, we have about three  
2 magnitude 5s per year across the state. So this is a very highly active region.  
3 We know that.

4           And we also broke it down by regions. People wanted to know how  
5 does the northern part of California from this line up, compared to that in  
6 Southern California and you can see Northern California again when the whole  
7 state has a 99 percent probability of having a magnitude of 6.7 or greater  
8 earthquake. Northern California has 93 percent and Southern California 97  
9 percent. So again, this is -- this just gives us the statistics that we need to try  
10 and understand it. And when you look historically, a magnitude 6.7 typically  
11 occurs about every five years in California; 7 every 11 years, 7 and a half every  
12 48 years. And a magnitude 8 we probably haven't even recorded one yet but it's  
13 650 years or so.

14           So the other portion of the model that we need to take into account  
15 when we are designing or making hazard maps is we need to understand once  
16 the earthquake occurs how strong will the shaking be from that earthquake? And  
17 so we've worked a lot with different organizations, PEER, for example, the Pacific  
18 Earthquake Engineering Research Center is one who we've worked with to try  
19 and develop these ground motion models for -- that we are using in our maps.  
20 And you can go now to the PEER, which is at UC Berkeley. It's a major center,  
21 it's sponsored by PG&E as well as many others, but it's a place where you can  
22 go get information on all the different earthquakes that we have records for. And  
23 so this is a wonderful database that was put together to try and standardize the  
24 way we model ground shaking. When we do that -- when we make previous  
25 models, we had a certain amount of data but when they went through and

1 collected all the data that they could find in these regions, that's shown in blue.  
2 So the previous data is shown in red; the new data is shown in blue. You can  
3 see that as they put these data together they were able to collect an additional  
4 large amount of data which makes us have more confidence in your ground  
5 shaking and also gives us better estimates of uncertainty as Annie talked about.

6           So they collected a worldwide, 172 worldwide earthquakes, 1,400  
7 recording stations. There's a lot of data that goes into developing these models.  
8 When they did that, they realized that the ground motions were coming out  
9 slightly lower than they had previously thought. So the older equations are all  
10 shown in blue. This is for a one second spectral [spelled phonetically]  
11 acceleration value for magnitude 7.5 on a firm rock site condition and so the blue  
12 curves are what we previously used and the red curves are the new NGAs what  
13 they call those curves, NGA equations. And you can see that for one second for  
14 the large earthquakes they are typically lower.

15           And so, this again, just to show the process, a lot of people were  
16 wondering, is this a real effect? And so we made these modelers test all these to  
17 try to look at the residuals, to try and tell us, do these apply to worldwide  
18 earthquakes or do they apply to California earthquakes? Is California different  
19 than the world? There's lots of questions that we had, and we went through this  
20 process to try and really drill down and understand these equations, and in the  
21 end the science community really felt that these new equations were based on  
22 better data new updated models and that this was a better way of assess the  
23 ground motion hazard.

24           So these are the maps that we produce. Annie showed these. We  
25 use a -- excuse me -- we use a two percent probability of exceedance in 50

1 years, and Annie didn't get into that. Annie says that the NRC is a 10 to the  
2 minus four. We use four times 10 to the minus four in the building code industry,  
3 so it's a little bit -- the nuclear industry is a little bit more conservative. They  
4 actually are a little higher ground motions than we would because this is what  
5 the building code industry felt like was a reasonable model for developing  
6 building codes. So two times 10 -- four times 10 to the minus four, or two percent  
7 probability of exceedance in 50 years. And these are maps -- we have published  
8 versions on our website, and I'll talk about our website in a minute.

9 I'd mentioned to you that for one second spectral acceleration that  
10 the ground shaking models were lower and that didn't bring down the ground  
11 motions by about 20 to 30 percent across much of coastal California. And so you  
12 can see in this map the ratio of the 2008 maps to the 2002 maps, and the blue  
13 colors are about 65 to 75 percent of the previous values. So they have come  
14 down.

15 This is a picture that -- or a slide that shows for different regions  
16 across Southern California and northern California and other places in the United  
17 States how the ground motion or the ratios of the ground motion -- for example;  
18 in Los Angeles the ground motions are 93 percent of what they used to be. All  
19 the red percentages are lower by more than 10 percent. Now, in the building  
20 code industry they actually did some things. They decided to use the maximum  
21 component of ground motion so in the end the ground motions didn't actually  
22 come down by 20 percent they pretty much stayed where they were. So they are  
23 about 20 percent higher than these values. But the actual ground motions did  
24 come down as a result of those ground motions prediction equations that I  
25 showed you previously from PEER.

1                   I wanted to show you on our website we have a wonderful tool that  
2 allows you to go break down the hazard for a particular site so I ran this hazard  
3 model just went to our website but in the latitude and longitude of San Luis  
4 Obispo, and this is what comes out. What it tells you is on this axis you see the  
5 distance from the earthquake. On this axis you see the magnitude of the  
6 earthquake. Excuse me. And these are all the earthquakes that are contributing  
7 to the hazard in San Luis Obispo, so you can see -- oh, thank you -- you can see  
8 that the major contributors to the hazard are -- in San Luis Obispo are the  
9 Rinconada, the Hascre [spelled phonetically], the Los Osos, the same ones  
10 you've been talking about, also the San Luis Range. Those all contribute about  
11 65 percent of the hazard. Now, we also have a back ground component that --  
12 where we use the earthquakes, the previously recorded earthquakes to say  
13 where previous earthquakes have occurred in the past is where we think they  
14 might occur in the future, where larger earthquakes may occur in the future. So  
15 that accounts for about 32 percent of the hazard the background seismicity and  
16 the eight faults the San Andreas faults, in this case contributes about 4 percent of  
17 the hazard to San Obispo site. And you can do this at any site you want on our  
18 website. It's all interactive and you can go there and put in your latitude and  
19 longitude and get anything.

20                   We also have for the 2002 version of our maps we haven't quite  
21 gotten that for 2008, you can do a geographic deaggregation which actually will  
22 show you the faults, it shows you the contribution, the contribution for each of  
23 these different faults in this case looks like the Los Osos is very important to San  
24 Luis Obispo because it's so close, because it's so close. The Hasgret [sic] Fault  
25 and the San Andreas Fault out here plus all the back ground seismicity is shown

1 here as smaller bars because it doesn't contribute quite as much. So this is all  
2 available, again, these are things you can look at when you go to our website.

3           The other thing we've been trying to do is we try and look at  
4 different ways of testing our hazard maps because we don't want to put out  
5 something that isn't robust, that isn't something that we can stand behind. So  
6 one way that we test it, is the USGS is over the last several years created what's  
7 called "Did You Feel It?" maps. So after an earthquake, maybe some of you  
8 have done this in the past, where you feel an earthquake, you go to the USGS  
9 website, and you can mark in there exactly what kind of the intensity it was, what  
10 shaking you felt, and what you observed at that site, and we get thousands and  
11 thousands of responses from people when we do this. And we compile all those.  
12 All that data is available.

13           And this isn't showing up very well, but what I wanted to show you  
14 was just that when you take one of our older hazard maps here which is like 10  
15 percent 50-year ground motion map, and you look at five years, so this is for 50  
16 years, and we have five years of recorded data, what you want to see is you  
17 want to see it start looking a little bit like your map. And it is looking like that. In  
18 many places when you take a big region like this, you can see the highs up here  
19 in Washington, and these are all earthquakes that occurred after that map on the  
20 bottom was made. So you can see that the area up here in Washington has  
21 been active, and we show that in our map the area down here in Southern  
22 California this area over near Landers is active, and we have that. When you go  
23 back east, you can see these different yellow points here and they all correspond  
24 to these spots that we have in there. Really what that's saying is basically that  
25 where the earthquakes have occurred previously is where they are going to

1 occur, but that's part of our model. We just wanted to test that model, and so we  
2 look at this Did You Feel It? data, we look at shake map data, and we try and  
3 really understand how and if there are ways that we can test these grounds  
4 motions.

5           Now, Annie wanted me to really quickly mention some of the  
6 criteria for building codes, and we do make the building codes maps, too, and it's  
7 a combination of deterministic and probabilistic ground motions that are used to  
8 make up the building codes. So I'm showing you here deterministic map which,  
9 again, just is if you have an earthquake what do you think the ground motions  
10 might be, either the 86th percentile or the 50th percentile, and so we make those  
11 maps and then they are put together -- the engineers feel like they can't design  
12 for ground motions that are too high for buildings. And so they want to truncate  
13 them, and so there are different ways that we truncate these things, and so these  
14 are all specified by the engineering community. And we take the advice of the  
15 engineering community because we are not engineers. We don't try and tell  
16 them how to build buildings. We just tell them what we think are the best ground  
17 motions -- what are the estimates of the ground motions at their sites and they  
18 make maps like this that are, again, a combination of probabilistic and  
19 deterministic truncated at .6 G to some level.

20           So I won't go into detail there, but what I wanted to kind of conclude  
21 with were some of the products that we have on our website. And in particular,  
22 you can see our website is [earthquake.usgs.gov/hazmaps](http://earthquake.usgs.gov/hazmaps). If you go to  
23 [earthquake.USGS.gov](http://earthquake.USGS.gov), you'll be at our NEIC, which is where we post all the  
24 different earthquakes that have occurred. You can see the shake maps. You  
25 can see the Did You Feel It?, the pager which tells you kind of roughly how much

1 damage you think in real time how much damage you might have from any  
2 particular event, and then if you go to has maps site then you'll see all these  
3 hazard products. And what we have basically are the U.S. National Seismic  
4 Hazard Maps and all the input information. We have analysis tools like the  
5 deaggregation that I showed you earlier, where you can go in there and select a  
6 site and understand exactly which faults are contributing most to the hazard at  
7 that site. You can go in there and see all the seismic design values so this is hit  
8 by tens of thousands of people hit this site every month because every time they  
9 design a building they have to go to this site and pull off the design values. We  
10 make urban hazard maps, which we're making for many areas across the  
11 country. We have deterministic scenarios. We have time-dependent ground  
12 hazard maps. We have a U.S. Quaternary Fault and Fold Database. Again, I'll  
13 show you a picture of that in a second, and then we have some tutorial  
14 information, Hazards 101. So you'll have a chance to be able to go in and learn  
15 more about what these hazards are.

16           We have probabilistic fault displacement hazard. We're working  
17 with the California geological survey to try and understand if you build right on a  
18 fault it might be different because you could have some huge displacements, and  
19 we have some ways of estimating what the likelihood of those faults would be.  
20 We make risk maps. So we estimate, for example, for the probability of having  
21 slight damage giving a certain building code, and we make different maps like  
22 this to try and assess for people what is the risk in the area. This area here is for  
23 Los Angeles and this is an area back in Missouri and Tennessee over here.

24           We have, again, our seismic hazard curve and uniform hazard  
25 response spectra. These are -- this is the website the Web tool that engineers

1 like which building code they are interested in, the addition, data addition that  
2 they are interested in, put in their latitude and longitude, and they can pull out  
3 either hazard curves or design values that they can use in their design of a  
4 building. We have the Quaternary Fault Database, which has not only the faults  
5 that we use in the model but everything that we know of that has the quaternary  
6 offsets so we look at everything that -- those million-year-old faults and put them  
7 in this database so that people could go in there and really look. You could go  
8 there and put -- look in the area near San Luis Obispo and pull up all the different  
9 faults and some of them we haven't included in our model because we may not  
10 have good information about those, but all the different faults that has been  
11 mapped are included here. And so that's a good resource for you if you want to  
12 find information on the faults near a particular site.

13           And finally I want to conclude that we are just beginning the  
14 process again. We do this over and over, and we're about ready to start our next  
15 version of the hazard maps for 2013. We'll have California workshop in 2012.  
16 There's a new UCERF process, which is going on, which is the Uniform  
17 California Earthquake -- Uniform California Earthquake Rupture Forecast model  
18 will be -- is going on now. And what they are trying to look at are issues like how  
19 often does one fault jump on to or does an earthquake jump from one to another  
20 fault? That's a very important issue. It's cluster models, those kinds of issues.  
21 And we're going to have workshops and discussion about that. They are all  
22 open. So any of you are invited to attend those. We'll have more on the ground  
23 motion attenuation relations for the Western United States. PEER is now  
24 sponsoring a new version of the NJ [sic]. They are going to update it again. And  
25 so we're working with them to try and make sure that these updates come into



1 these maps. There's a new user-needs workshop that will happen we'll have all  
2 the draft maps again, and these are, again, for the next version of the ASCE 7  
3 and IBC versions.

4 So again, this is like a continual hell, you know, just keep making  
5 the updates of these maps. But we want to just make them better and better  
6 every time and we need the input of the science and the user-community to try  
7 and help us to get the best information available that we can put into these maps  
8 so that they are the most robust and best maps out there. So, thank you very  
9 much.

10 [applause]

11 MR. MAIER: Thank you, Drs. Kammerer and Petersen. We are  
12 way ahead of time now, so all sorts of questions on probabilistic hazards and  
13 probabilistic analysis. Remind you to please raise your hand and if you have a  
14 question for one of the two panel members based on the presentations that were  
15 just given, as you can see we're building towards an end point, moving closer  
16 and closer towards applying a lot of this to the plant nearby as well as here in the  
17 area. Okay. Butch, you ready?

18 MR. BURTON: All set.

19 MALE SPEAKER: All right. I also would encourage anybody who  
20 doesn't want to necessarily stand up and be videotaped, if you want to put your  
21 question on a 3x5 card, Butch and I have those. You can put your contact  
22 information and please write legibly again, and we'll get that to someone who can  
23 get an answer back to you. Questions? I see one here in the middle.

24 MALE SPEAKER: [unintelligible], just a clarification. So it seems  
25 that with the new data, the [unintelligible] for California, are you guys going down

1 while on the other side of the U.S. the new data from the, since it suggests that  
2 the hazard is increasing is this consistent with more data on that side indicating  
3 something?

4 MR. PETERSEN: [inaudible] So the question is, as I understand  
5 it, is why is it that the ground motions seem to be coming down in the west where  
6 they might be going up in the east? Is that the question? You know, I don't,  
7 actually for the last version of the maps the ground motions came down in both  
8 the east and the west and so there -- but it's not a simple thing because some  
9 ground motions actually go up and some go down. There were lots of -- I  
10 simplify it when I say that they came down because they did, and I showed you  
11 the maps in the best but there are places where the ground motion were actually  
12 higher it just depends on the, a lot of different features of the faulting. For  
13 example, those new ground motion models take into account the dip of the fault  
14 and whether you were on the hanging wall side, or if you are above the fault, or  
15 whether you are on the side of the fault, and so all those features come into play.  
16 So I didn't point out but Santa Barbara, for example, went up compared to a lot of  
17 places, and it's because of the dips of those faults, some of the depths of the  
18 faults have changed.

19 In the east, the ground motions have been -- have changed a little  
20 bit but it's mostly because of one new ground motion equation that was added to  
21 the mix and what was determined was that for the east we needed to learn more  
22 about those ground motion models, and so there's a whole effort -- NRC is  
23 actually sponsoring a lot of it. It's call the NGA East. So it's following in the  
24 footsteps of the first NGA and trying to use that, the best elements of that  
25 process, to try and develop new models for the east. We don't really know where

1 those are going to end up. But I can just say that there's a lot of more uncertainty  
2 in the ground motions in the east than there are in the west because we haven't  
3 recorded any of the large earthquakes, so it's difficult to assess that. Here we  
4 have a better estimate of what ground motions can occur in an interpolate kind of  
5 environment where you are right near a big crustal earthquake. Other  
6 questions? We'll go to Sherry [spelled phonetically] first.

7 FEMALE SPEAKER: Hi. I'm not sure I'm going to get this out right,  
8 but anyway, the probabilistic assessments, which is what all this was, is based  
9 on data, and there was so much data there I couldn't understand much of  
10 anything but --

11 MR. MAIER: You weren't alone.

12 FEMALE SPEAKER: -- oh, I'm sure. I know. But the data -- most  
13 of the complex data seems to come from recent observations because it's such a  
14 new science on earthquake and all and you can find out distant past stuff by  
15 paleoseismology or whatever the word is, but that's not that detailed. I mean,  
16 you find something in a trench under the ocean you are not going to get all the  
17 detail that you get from an earthquake that's happening now. So, but on the  
18 other hand -- so you've got that, a lot of data from recent stuff, not data from  
19 more than a few decades, not much.

20 But also you have the population growing and you have building  
21 happening. So you got to do something. They have to come up with regulations.  
22 And they sound positive and good and hard-core, but they can't really be all that  
23 hard-core because it's still such a new and growing science. So the thing that  
24 bothers me is that it sounds like everything's under control and understanding  
25 things when it can't really be because as you say you've not even recorded a

1 very large earthquake, you know, well, you weren't here to record 1906, and I  
2 don't know how big that earthquake was because a lot of the problem there was  
3 the fire. So what's my question? I guess I just wanted to comment that it sounds  
4 more wonderful than it really is. Okay, maybe you can answer.

5 MR. PETERSEN: Okay. I mean, I agree that this science has a lot  
6 of uncertainty in it. I tried to express that, like you pointed out, in the east we  
7 hadn't recorded a big earthquake. And so it's difficult for us to predict what a big  
8 earthquake will look like. That's true, what you are saying. I think what we've  
9 tried to do is look at -- there are two parts to this. I mean, there are the ground  
10 motion part of it and there's the source part, and we haven't recorded big  
11 earthquakes on those faults near San Luis Obispo, big earthquakes other than  
12 the 1927 Lompoc earthquake was, again, on the Hosgri Fault, I think or  
13 somewhere near that. No, no. Okay wherever that was. There's a lot of  
14 discussion about that but the Lompoc earthquake was one that did occur in this  
15 region.

16 So that's -- but we have a lot of earthquakes in the same type of  
17 environment so that gives us a lot of confidence that future earthquakes will look  
18 kind of like that so when we look at places like Haiti, and we've seen that big  
19 earthquake that occurred there, we can understand those ground motions from  
20 these ground motions equations that has been developed. When big  
21 earthquakes occur in Chile, we can kind of look at it and say how much do they  
22 differ, and sometimes they do differ, and that's why we're continually updating  
23 them. If we knew everything, we wouldn't be in the process of updating these  
24 every six years. So I don't want to make the impression that we know everything  
25 about earthquakes. I think you know that that's not true. What we do is we use

1 all the information that's available to us, and that's on the ground motions.

2           On the source side we also -- we have certain faults that have been  
3 mapped and we use those -- people go down and do the best job they can of  
4 studying those. We also account for earthquakes that we don't know about. For  
5 example, I didn't talk too much about our background seismicity model, but we  
6 assume that where earthquakes are occurring or where future earthquakes are  
7 going to occur, which seems to be a model which is very likely to occur. I mean,  
8 people have tried to do statistical studies of that and find that like 75 percent of  
9 the time in the east at least, that they seem to occur in regions where they have  
10 occurred in the past. Now, there's some places where we don't know, I think  
11 that's true, but we've tried to use everything we can from the geodesy from the  
12 GPS data to the geology that has been recorded, plus we've accounted for  
13 earthquakes that we don't know about just by looking at where the seismicity is --  
14 where the small earthquakes are occurring.

15           So I hope that answers kind of your question. I think you are  
16 bringing up that this is a very uncertain kind of thing trying to predict earthquakes  
17 where we haven't seen them. I think we are using all the information we can to  
18 try and get at that question and resolve that issue.

19           FEMALE SPEAKER: I certainly appreciate that. But the trouble  
20 with probabilistic studies is that when people give examples of it, like in the very  
21 beginning today, you know, you're speeding and what's the chance that some  
22 policeman is going to see you speeding, well, the consequences of your being  
23 caught by this earthquake near a nuclear power plant, you know, is not a  
24 speeding ticket, but it's radiation covering Southern California.

25           MR. MAIER: I think we'll get into that in some of the more --

1 FEMALE SPEAKER: I know you'll get into that tomorrow but it's  
2 something that can't be forgotten and with all of the studies that you're doing you  
3 are getting closer and closer but you are still a distance away and it wouldn't  
4 matter so much if it were just ordinary day life, you know, people living in huts or  
5 people living in careful buildings, but when you have something where the  
6 consequences are just astronomically huge compared to ordinary stuff -- okay.

7 MR. MAIER: Thank you --

8 DR. KAMMERER: Let me just address that really quickly --

9 MR. MAIER: Okay.

10 DR. KAMMERER: -- and not keep saying we are going to talk  
11 about it tomorrow, let's talk a little bit about it right now. So there was a mention  
12 of the building codes and things like that, and I think one of the things that you've  
13 seen everyone say, I think, uncertainty has probably been over and over and  
14 over in every talk, and I think that that's one of the benefits of the probabilistic  
15 approach that we use now, and I'm going to have another talk again in the  
16 afternoon, is that the incorporation of uncertainty, really trying to understand what  
17 we don't understand, and to try to make sure that we incorporate that in design  
18 with that you on the ultimate risk. Because there was a discussion before that it's  
19 not only getting to the hazard, you know, we saw the comparison with the Bam  
20 [spelled phonetically] earthquake where you have tons of thousands killed, and it  
21 was really about the design in the buildings that were there for that same hazard.

22 So it is both. And you are absolutely right, so I'll talk about  
23 probabilistic risk assessment this afternoon covering another talk but that's  
24 something that we always have to keep an eye on. And that's one of the  
25 benefits, I think, of the way we approach things now, is looking at that uncertainty

1 as well, because, I mean, you are right, you know, we'll continue to learn more  
2 and more and more over time, but let's make sure that we at least try and wrap  
3 our heads around what we don't know and account for that as well. So I think  
4 that's very insightful, your comments.

5 MR. BURTON: Okay. We've got one over here. Many thanks to  
6 this young lady.

7 MS. THATCHER: My name's Janet Thatcher. I have a question  
8 about the Parkfield data. Is there anything that you can say as a summary of  
9 what you might have learned from the data from the recent Parkfield earthquake?

10 MR. PETERSEN: So Parkfield, again, the USGS made a forecast  
11 of an earthquake at Parkfield, and we saw the earthquake that occurred back the  
12 '20s and then again I think in '66 or something like that, so we saw that it had a  
13 typical 30-something year. I don't have all the details, but recurrence, an  
14 average recurrence, and it seemed like there were a lot of similarities between  
15 those two earthquakes. And so we felt like that was a reasonable way to say that  
16 in another -- 30 year, 30 -- there was one period that was shorter than the others,  
17 and so we thought we felt like we could make a forecast about how likely that  
18 earthquake was and do something about it, and it actually didn't occur when we  
19 thought. It occurred later. It has occurred by now, but it didn't occur in the period  
20 that we thought. So one thing I think we've learned is that we probably  
21 underestimated the uncertainty in that process. We thought we were looking at  
22 the uncertainties at a reasonable way, and we weren't. So I think if anything,  
23 we'd probably say that we should have increased our uncertainties and how likely  
24 that was.

25 We still have a lot to learn about, again, that was an earthquake

1 prediction evaluation. We really wanted to try and see if we could predict  
2 earthquakes. And that's still the "golden ticket." If we can get -- if we can really  
3 learn to predict earthquakes it would be a lot easier for everybody, but we haven't  
4 gotten to that stage yet. So we just need to really try and concentrate on trying to  
5 understand how likely -- and for these kinds of models that we're looking at, we're  
6 going to see the Parkfield go off hundreds of times in the next thousand years, or  
7 10,000 years. You're just -- because if it's going off every 30 to 50 years it's not  
8 going to make that much difference as far as the rate of earthquakes because we  
9 get a lot of earthquakes in Parkfield, and we will continue to get earthquakes in  
10 Parkfield.

11                   So for these types of maps, I think we will have a high ground  
12 motion near Parkfield no matter what because it just goes off so often. But I think  
13 we cannot predict earthquakes yet. And that's the other message that I think we  
14 have to realize.

15                   MR. MAIER: We have a question here.

16                   MR. BARD: Jeff Bard [spelled phonetically], Upland Research  
17 Science Action [spelled phonetically]. I hope that when you're working you don't  
18 truncate your studies at the U.S.-Mexican border. I'm sure you probably don't.  
19 And the people who live near the San Onofre reactor were probably very grateful  
20 for that.

21                   My background is more in epidemiology and public health, so some  
22 of this terminology is new to me. I do expect to encounter the next generation of  
23 Dr. John Gaffman [spelled phonetically] or Dr. Carl Johnson [spelled phonetically]  
24 out there. The question is, are they going to be credible? Let's focus on these  
25 quaternary consensus fault databases and secondarily on the deaggregation



1 Web pages, because as you hinted, those are going to be critical in developing  
2 some questions tomorrow and going forward. So the clarifications that I request  
3 are actually pretty simple.

4           First, I'm going to ask you to expound a little bit more about what  
5 I'm calling the QCF, the quaternary consensus fault database. And secondarily,  
6 please explain to us how the data in that is incorporated in the deaggregation  
7 Web page. So to more specifically characterize the question, does the QFC  
8 database include all suspected faults for which there is some data, or does it  
9 merely include those faults upon which there clearly is a scientific consensus?  
10 And that may be clear to some, but in epidemiology I haven't encountered that.  
11 So please clarify whether this is an exclusive or an inclusive consensus.

12           And secondarily, then, please explain whether the QFC database is  
13 actually fully reflected in the deaggregation presentation at this stage. And if it's  
14 not, do you think it would be a good idea if going forward they go ahead and  
15 create different versions of the deaggregation page? Because that will actually  
16 answer the question that was raised earlier about whether Diablo can be said to  
17 be on a fault, because the answer is, it's a probabilistic answer and it's really an  
18 aggregation of several real or suspected faults. So I hope the question's clear. If  
19 not, please -- [break in audio] -- and I'll clarify it.

20           MR. PETERSEN: So let me try and tell you what I know about that.  
21 We make -- we have this quaternary fault database, and we work with all of the  
22 geological surveys in the United States to try and get the best information that  
23 they have on each of these different -- all the different maps that have been  
24 made and all of the information on how these faults were named, what the ages  
25 of the offsets were. There are lots of different parameters in that database. And

1 this database is the basis for our seismic hazard maps. But we do not include all  
2 of our faults from the quaternary fault database in our hazard maps because for  
3 some of these we don't know whether -- we don't know much about their activity  
4 rates. Our hazard maps are for -- were primarily developed for building codes.  
5 And nobody wants to have someone just put in a fault that is very poorly  
6 understood into something like a hazard map that would cause someone to --  
7 when there's not enough information on it -- when it's someone's speculating.  
8 Someone could put in anything they wanted to in this. So we work with the  
9 geological surveys to try and get the best information in this database, and we've  
10 put in all the information where there are trenches, where trenching has  
11 occurred. And then from that, we developed what is the consensus fault  
12 database which are parameters that are actually applied in our hazard maps.

13           So what I'm trying to say is we don't include every single fault that's  
14 ever been mapped in our database because there are lots of faults that are most  
15 likely not active, that are in that quaternary fault database that are not included in  
16 our maps; and we don't know anything about them. If there was more  
17 information on that we would certainly consider that. But we have a standard, a  
18 publishing standard that someone really has to have published this in some way  
19 before we include it in our hazard maps. Does that make sense?

20           MR. MAIER: Does that give you the first question, Jeff?

21           MR. BARD: I'm still a little confused as -- if the maps and the  
22 deaggregation, if that's all the same data or if there's different versions of the  
23 aggregation, because it seems apparent we need a need for another set of  
24 deaggregation presentations for those faults which are less clearly established in  
25 the scientific consensus.

1           MR. PETERSEN: Okay, so the deaggregation is really taking apart  
2 the hazard and saying, which different faults are contributing to the hazard at that  
3 site -- which magnitudes, which distances are contributing to the hazard? And  
4 what I'm saying is that we take the quaternary fault database as the subset of all  
5 the different faults that we're considering, and then we bring that down to the  
6 number of faults that really have consensus of the activity rates for those faults.  
7 And then that's what we put in the hazard maps. That's what we make the  
8 aggregations for.

9           So we don't really de-aggregate because if you just see a fault, it's  
10 difficult to say how active that fault is. When you can go in there and you can  
11 see a slip rate that that fault has actually slid a certain amount in displacement in  
12 a certain amount of time, then you can estimate that there's an activity rate  
13 associated with that. But if you don't have that information, if all you see is just a  
14 fault on the ground, how do you tell how active that fault is? How do you  
15 determine whether that -- I mean, it's something that a geologist has access to all  
16 these faults. So when they do reports for buildings, for example, they might look  
17 at a lot of different faults in the area and they might even make some  
18 hypothetical guesses at what those faults, the activity rates of those faults. But  
19 we don't really have any scientific basis to assign an activity rate to that fault. All  
20 we have is a location.

21           So it would be difficult. In order to really put that into a hazard map,  
22 we'd have to determine how -- does this occur once in a million years? Does this  
23 occur -- because we're looking at a 2,500 year, one in 2,500 year recurrence. So  
24 mostly, what we care about is for these maps, is looking at the faults that rupture,  
25 you know, in 10,000 years or less, but we don't really know about -- the other --

1 again, these are the -- quaternary fault database is the basis for our hazard  
2 maps, but it goes through another step in order to really come up with consensus  
3 values for those faults that are included.

4 DR. KAMMERER: I guess I would go back. So, as I mentioned,  
5 [unintelligible] probabilistic seismic hazard assessments. What you do is you  
6 look at all of the possible scenarios that could contribute to the hazard at your  
7 site. So you look at all of the faults that you have in your model, and the  
8 parameters, and each possible event on that. And you say, "Okay for that  
9 particular event, what's its likelihood and what does it mean at my site?" And you  
10 take all of that hazard from all of these possible events and you integrate it all,  
11 you pull it all together and that gives you your values. Well for each of those  
12 scenarios, that magnitude and distance, there's some hazard associated with  
13 that that gets added. What you do is every single scenario, you drop it into one  
14 of the bins of magnitude and distance as you're doing it.

15 So really, all the deaggregation is, is taking all those possible  
16 scenarios that fed into your overall hazard and putting them in whatever  
17 magnitude and distance bin they came from. And then at the end, you say,  
18 "Okay, well here's the overall hazard I've gotten from integrating all of these  
19 scenarios together, and this is what the different components are."

20 MR. MAIER: Any follow up, Jeff?

21 MR. BARD: Well, I mean, since you asked, we could go on a long  
22 time. Very clearly, these were just designed for regular building codes. They  
23 were not specifically designed for nuclear power plants. And I think we need to  
24 get some funding to you guys through our representatives so that you can  
25 actually go ahead and develop a set of deaggregation presentations for the

1 general public and the scientific community, which are based on different  
2 assumptions; because somewhere out there, there are going to be these  
3 mavericks who may turn out to be right about something. And we need to, you  
4 know, look at this thing every which way. So thank you for your answer and I'll  
5 certainly look -- [break in audio] -- let other people know if you guys seem to  
6 need money for this. Thank you.

7 MR. MAIER: Dr. Kammerer, anything else on that or are we done?

8 DR. KAMMERER: I suspect the USGS would appreciate the  
9 support of additional funding for the hazard maps.

10 MR. PETERSEN: And again, what the funding would really go into  
11 if you're going to do that exercise is to go look at all those faults. And I assume  
12 that that's been done for this region, that people have looked at all those different  
13 faults. But I don't know. It's happening now? Okay, so that's what -- what you  
14 need is to have a geologist to go out on the ground and look at each of those  
15 faults and determine how active that fault is.

16 MR. BURTON: Okay, any questions on this side of the house?

17 MR. MAIER: I've got one from Barbara.

18 MR. BURTON: Okay.

19 FEMALE SPEAKER: Earlier, Victoria Langenheim mentioned that  
20 through the seismic imaging might be helpful, but if it were also included  
21 supplemental coring or sediment studies -- is USGS planning anything like that  
22 for the [unintelligible] or shoreline, off shore? Or say the Los Osos onshore?  
23 Any trenches or sediment cores that you might be planning?

24 MR. PETERSEN: I don't know of any analyses that are taking  
25 place in those regions. You know, really, there are different communities that do

1 this trenching. Some are the private industry goes out and does some of these  
2 trenches. The USGS has a number of different geologists that go out and the  
3 like that do these kinds of studies. But it's difficult because they're just so many  
4 places around the United States and there aren't very many of them to actually  
5 do that. So, right now I don't know of any particular trenching studies that are  
6 being planned for those faults. Do you know of any, Annie?

7 MR. BURTON: Any other questions?

8 MR. MAIER: We'll go to June first.

9 FEMALE SPEAKER: I want to get a clearer picture of your  
10 probability. You said that the 6.7 Northridge quake, there's a probability of 99  
11 percent. And then 7.5 is 46 percent, which is almost half. Is that for the whole  
12 State of California, or can you --?

13 MR. PETERSEN: Yes, that's for the whole state of California.

14 FEMALE SPEAKER: So basically, there's even a four percent  
15 chance that we will have an eight like some of the huge earthquakes around the  
16 world. It's a possibility.

17 MR. PETERSEN: That's what our model shows that we would  
18 expect that -- typically the different size of earthquakes are like 7.9, I think, for the  
19 1906 and 7.8 for the 1857 ruptures. And then there's uncertainty in those sizes.  
20 So it gets above eight in some cases. So it's a lower probability.

21 FEMALE SPEAKER: So it's just a little under half, though, for a 7.5  
22 or above?

23 MR. PETERSEN: Right.

24 FEMALE SPEAKER: Right, okay. And in the other one, I wanted a  
25 little bit more clarification about where you said, "Sixty-five percent of the

1 earthquakes or the 13 around here that we keep talking about and that 32  
2 percent is the background seismicity.” Can you go a little deeper into that and  
3 what ramifications that has potentially for the nuclear power plant?

4 MR. PETERSEN: Well, you know, again, this is a very -- seismic  
5 hazard can be kind of complicated. And what I did was I did a deaggregation for  
6 the hazard at San Luis Obispo. And what that tells us is how are each of those  
7 individual faults contributing to the hazard? But it has to be at a two percent  
8 probability of exceedance in 50 years, or at four times  $10^{-4}$ . It  
9 would be different if you used a different level. Like the NRC said they were  
10 using  $10^{-4}$  -- one times  $10^{-4}$ . So you could go  
11 onto our website and do one times  $10^{-4}$  and do a deaggregation.  
12 It might differ a little bit. But for the building codes, those are the earthquakes  
13 that contribute most at that particular level.

14 And again, the faults are contributing about, I think -- what did I  
15 say? -- about 60 percent to that hazard at two percent probability of exceedance  
16 in 50 years. And the background model which accounts for other earthquakes  
17 that we haven't seen that -- just using the model that where previous smaller  
18 earthquakes have occurred, or where the future big earthquakes will occur, that  
19 was about 30 percent or so. And a big San Andreas rupture is far enough away  
20 from San Luis Obispo, but it contributes, but not as much as those others. It  
21 would contribute if the ground motions happen to be exceedingly large in a  
22 particular earthquake on the San Andreas Fault.

23 MR. BURTON: Okay, good.

24 MS. MOFFATT: I'm Carolyn Moffatt from Port San Luis Harbor  
25 District. Probabilistic assessments consider the probability or likelihood of

1 different events over time. I'm wondering what span of time you use and if that's  
2 applied consistently?

3 DR. KAMMERER: Yeah, what probabilistic hazard assessment  
4 looks at is level of ground shaking -- we had an annual probability of a certain  
5 ground shaking happening at any point in time. So what we look at is the one  
6 times 10 to the minus four as a starting point. We go from one times 10 to the  
7 minus four and one times 10 to the minus six. That means during a particular  
8 year, an annual probability, it had -- there's only a one in 10,000, a one in  
9 100,000, or one in a million chance that that ground motion would be exceeded.  
10 It's an annual probability is how the assessment's done. And it can be translated  
11 into different likelihoods over, say, they use a 50 year because that's a typical  
12 building lifespan. And so that's why the building codes are focused on two  
13 percent in 50 years or, you know, five percent or 10 percent in 50 years. But we  
14 look at it a little bit differently as an annual probability of a certain ground motion  
15 being exceeded. So basically, we're looking at one in 10,000 as a starting point  
16 and then we work up from there.

17 And one thing I would actually just mention because you actually  
18 heard about the four times 10 to the minus four -- one of the things that we talked  
19 about it that there's the hazard and there's the design. And that gets you to your  
20 risk calculation. The design part of a typical building and a nuclear plant are  
21 very, very different; whereas, in the building code they look at four times 10 to the  
22 minus four as a life safety criteria. So the building doesn't have to be functional  
23 afterwards, but people shouldn't be killed in it. In a nuclear plant, that's the linear  
24 design. So there should be no onset of inelastic deformation. So there's the  
25 hazard, which is what we're talking about, and then there's also the design



1 requirements that are associated with the hazard.

2 MS. MOFFATT: Okay, thank you.

3 MR. BURTON: Any other questions? Okay, we're running a little  
4 bit ahead of schedule, and I am trying to decide whether or not we need to hold  
5 to the 3:15 start time for session four, or start that a little bit earlier. So let me  
6 ask a couple of questions. First, everyone in the audience, do you know of  
7 anyone who is not here who was planning to be here for the 3:15? We've got a  
8 couple of people, which lends that we may not be able to start earlier. For the  
9 folks who raised their hand, it is going to be an issue if we try to start earlier?  
10 Okay, so it sounds like we probably should not try to start earlier and stick to the  
11 3:15. Everybody all right? Which means we'll just have a longer break? Okay.  
12 Let's do that then.

13 [break]

14 Session 4: Nuclear Power Plants and Seismic Hazard

15 MR. BURTON: My name is Tony Brown. I'm the NRC resident  
16 inspector here at Diablo Canyon. I'd like to welcome everyone to this session,  
17 Session No. 4: "Nuclear Power Plants and Seismic Hazard." I'd like to introduce  
18 the two speakers for this session: Annie Kammerer [spelled phonetically], who's  
19 just introduced in the previous session -- she's a senior seismologist at NRC  
20 headquarters in Maryland -- and Torrey Yee. Torrey is a civil and structural  
21 engineer for Southern California Edison at the San Onofre Nuclear Generating  
22 Station. Torrey performs seismic evaluations and qualifications of structures and  
23 equipment and supervises the civil engineering group at [unintelligible]. With  
24 that, Torrey --

25 MR. YEE: Hey, good afternoon. As you can see, my topic here will

1 be seismic design of nuclear plants. I'll present the objective, the seismic  
2 classification; I'll describe how we classify structures, systems and components.  
3 I'll go over the design process, and we'll talk about seismic monitoring, and also  
4 the seismic qualification of equipment.

5           So the objective is to discuss how nuclear plants are designed to  
6 protect against seismic hazard, or basically, how we design for seismic events.  
7 In terms of seismic classification, there are two primary categories to classify  
8 structures, systems and components, and you'll see there's an acronym SSC  
9 talked about in the nuclear industry. Safety related, needed to remain functional  
10 in order to maintain the safety of the reactor and prevent the release of  
11 radioactive materials outside. Those would be what we call safety related. Non-  
12 safety related is the capability and performance has no effect on safe reactor  
13 shutdown or potential offside release of radioactive material. So those are the  
14 two main categories of classifying structure, systems and components.

15           Now along with that then, safety related structure, systems and  
16 components are designated as seismic category I. That means they're designed  
17 to withstand the effects of an earthquake without loss of capability to perform  
18 their safety function. And that main safety function is to prevent the release of  
19 radioactive material. Examples of safety-related components, I mentioned the  
20 nuclear fuel assembly, the reactor vessel in the coolant system, and then the  
21 containment structure. I mentioned the containment structure only because it's  
22 the one that is the one that most people think of when they talk about the nuclear  
23 plant. And that is designed to prevent the release of radioactive material.

24           In terms of non-safety related structures, systems and components,  
25 these are what I'll term as non-seismic category I. The reason why I say they're

1 non-seismic category I only in that when you look at the industry various plants  
2 do have different seismic categories, such as two and three or something else;  
3 and therefore, just generically I'll just call that non-seismic I. And these things  
4 are designed for the building code, the national building code that people have  
5 discussed earlier. And its purpose is to protect the life and safety of people. It  
6 has nothing to do with radiological safety. And typical of these are schools,  
7 houses, office building, warehouses, et cetera. Examples of nuclear plant that  
8 would fall under this non-safety related category would be our turban generator,  
9 which its main purpose is to generate electric power, maintenance shops, and  
10 office buildings.

11 Now, I'll talk about the seismic design process. Our seismic design  
12 process complies with the NRC regulation, and it's found under 10 CFR, Part  
13 100, Appendix A. One of the first things we do in our citing of a plant is to look at  
14 the soil conditions, and they're evaluated to be stable, acceptable to support the  
15 plant structures. What I mean there is, is that we make sure that we don't have  
16 liquefaction on the site; we make sure that there's no faults directly under our  
17 structures; we also make sure that they're not in a landslide area. The other  
18 thing we do in the seismic design process then is that we obtain the maximum  
19 site ground motions when doing our design. And in doing so, we classify -- we  
20 have two categories, or I'll say two levels of earthquake. And the first one is what  
21 we call the safe shut down earthquake, and that is the maximum credible  
22 earthquake that the site would see if a seismic event occurred.

23 And then the other level is a lower-level earthquake which we call  
24 the operating basis earthquake. And this is usually at 50 percent level of the safe  
25 shutdown earthquake or it could be even lower than that. Structures are

1 dynamically analyzed then and for these ground motions to obtain the  
2 earthquake forces for design. And that's basically where the engineer does a  
3 mathematical model and does their analysis and usually by computer to see how  
4 a building would respond to the ground motion.

5           Now earthquake loads -- when we do that analysis we do that we  
6 get earthquake loads. And then our SSCs, again, our structure systems and  
7 components -- they're designed for earthquake forces in combinations with other  
8 loads such as dead weight. These would be your normal loads such as the  
9 weight of the concrete, the steel equipment. That would mean the building. We  
10 also have operating loads which, again, would be the equipment operating loads  
11 such as normal pressure and temperature. And then we have accident loads  
12 where we sometimes postulate scenarios such as a pipe rupture or, a pipe break,  
13 or tornado missiles. And these are other things that we do design a nuclear plant  
14 for. These -- then resulting structural response actions are -- response motions  
15 are then used to qualify equipment and components, meaning after we do our  
16 analysis with these earthquake loads, we look at the building responses and  
17 obtain the motions that we would see at each floor of the building so that we  
18 could then design the anchorage and consider the function of equipment within  
19 the building.

20           Then, structures and equipment are designed using national codes  
21 and standards with inherent safety margins. These include NRC regulations and  
22 guides and then you'll see the list of other codes and standards that are  
23 applicable when we do a design. The American Society of Mechanical  
24 Engineers, that's basically a code that applies to our piping as well as our  
25 containment; the American Institute of Steel Construction, that's the design of

1 steel; the American Concrete Institute, that's the reinforced concrete design;  
2 Institute of Electrical and Electronic Engineers, that governs our electrical and  
3 control equipment; and then American Society for Testing Materials, this  
4 basically defines the strength of materials and how we purchase that.

5           Seismic capability is robust. The first bullet, basically, proven  
6 design features. Over the years as we've experienced earthquakes from -- I'll  
7 start from 1971, the San Fernando earthquakes -- we learned a lot about how  
8 buildings should be designed, especially for reinforced concrete. And we then  
9 learned from some of the damage that was seen that we would have to make  
10 sure that the reinforcement that we have in the concrete is designed properly so  
11 that the building would respond in a, what we call a "ducto manner" [spelled  
12 phonetically]. What that means basically is that the building could basically still  
13 operate, or still stand up, without breaking apart, or what we call "brittle failure."  
14 That means then that the building could deform and not cause a failure or  
15 collapse of the building. We also have redundancy of equipment in the systems.  
16 In terms of our design, we always have two independent systems for our various  
17 safety-related systems. Again, this would mean that if we have to cool the  
18 reactor, we have basically two methods or two independent systems that would  
19 allow us to do that.

20           Another thing that we have in terms of robustness is design load  
21 combinations. They include accident loads. As I mentioned, we designed for  
22 pipe rupture. The theory is that we should be designing to prevent the pipe  
23 rupture and that's what we do, but still we still consider what if the pipe were to  
24 break and what loads that could do. And we look at that in combination with our  
25 earthquake loads. Safety margins and seismic capacity to prevent the loss of

1 function or failure -- again, there's safety margins, meaning we design things not  
2 to necessarily the breaking point, but to a level that is prescribed by our codes  
3 that would basically show that the structure could maintain its function, meaning  
4 it won't fall or fall apart.

5           Conservatisms -- as there was talk about earlier, earthquake  
6 ground motions. We have conservatisms in how that ground motion is defined.  
7 There was, you know, mention regarding the probabilistic and a deterministic.  
8 Well, when we do our design we kind of covered the whole envelope in terms of  
9 what is the maximum motion, and adding into that, a broadened spectrum.  
10 There was a design ground spectrum that you saw. To cover the frequency of an  
11 earthquake, we broaden it; we make it wider to cover what events we think would  
12 occur. Analytical methods, this includes damping values that we would use,  
13 where we don't use -- again, the worst or the best damping curve. Rather we  
14 use what is a conservative damping. We also combine, basically, the maximum  
15 earthquake that could occur in three directions. In general, you don't see an  
16 earthquake that would have your maximum motion in horizontal --in two  
17 horizontal directions and a vertical direction all occurring at the same time. Yet  
18 we take that worse case of assuming the worst motion in all three directions and  
19 take that into account in our design.

20           Acceptance criteria -- again, I mentioned that we design things to a  
21 conservative acceptance criteria. They're not designed again to a breaking point.  
22 But there's margin between where the structure components would survive in  
23 terms of an earthquake, or how they would perform during an earthquake event.  
24 Steel and concrete are designed for ducto behavior. Again, that means allowing  
25 movement without breaking. Seismic qualification [unintelligible] levels are

1 higher than the calculated seismic motions at the insulation location. Again, as I  
2 talked about, we predict or we estimate the motion at the various building levels.  
3 And then for the complex pieces of equipment that we cannot analyze, we do  
4 actual testing. And that testing usually requires that we test at a level 10 percent  
5 higher than what the building response is at each floor. And then this is all to  
6 basically provide assurances of withstanding the seismic event.

7           Seismic qualification of equipment -- this again is to demonstrate  
8 equipment well functioned during and after an earthquake. This includes testing  
9 and analysis. Part of that testing is to put the component or a piece of equipment  
10 actually on a shake table where we shake it to simulate the earthquake. The  
11 assimilates in certain conditions, meaning that we put the proper electrical signal,  
12 or we put the proper pressure and the loads that component or piece of  
13 equipment would see during normal operation. And these are again included in  
14 the testing. And then also when we have things that are too big to actually put on  
15 a shake table, we do mathematical modeling to simulate their operating  
16 capability.

17           Other seismic-related activities -- once we finish with the design,  
18 then you have to build the plant. And so as part of our quality assurance we  
19 make sure materials are verified to meet or exceed the minimum strength  
20 requirements. Again, those strength requirements are specified by the various  
21 codes, and we do testing again. For example, concrete, we make sure we meet  
22 our minimum strength requirements. There's also inspections after and during  
23 construction to again ensure that things are built to the way the engineers  
24 designed them. Then there's also testing involved to again make sure that things  
25 operate and function the way we design them.

1                   Finally, we have to plan as operating, there's surveillances. We are  
2 constantly doing surveillances, meaning we still go back and test various  
3 systems and equipment to make sure that it's operating properly. As far as  
4 containment, when they're what we call "post tension" type construction, we go  
5 back and make sure that the post tensioning cables are still within the calculated  
6 estimate for how much strength they have.

7                   And finally, maintenance -- that's a requirement for us to, again,  
8 maintain our structures, systems, and components so that they are not degraded.  
9 Just like you would for a car -- make sure that your oil is changed. Well we  
10 ensure things are kept in operating condition so that they can function during and  
11 after an earthquake.

12                   And finally, post earthquake response requires evaluation  
13 inspections depending on the level and the site recorded motion. When an  
14 earthquake occurs near a nuclear plant, we have procedures that require us to  
15 take certain actions depending on the level of the earthquake. And then that  
16 could be up to and including the shutdown of the plant.

17                   In terms of seismic monitoring, we have seismic ciligraphs [spelled  
18 phonetically]. These are located in various buildings in the plant, and they're also  
19 one in what we call the free field. That would be away from buildings, and it's to  
20 basically record what an earthquake would be at the site without being influenced  
21 by structures. This then records the ground and building motions during the  
22 earthquake. They are used then again to determine whether or not the operating  
23 basic earthquake is exceeded. If it is exceeded then the plant has to shut down.  
24 If it isn't exceeded, then again depending on the amount or the level of the  
25 earthquake, the plant does go out and do inspections and so on.



1                   Plants in high seismic zones will automatically be shut down when  
2 the [unintelligible] is exceeded. In the United States, basically Diablo Canyon  
3 and San Onofre, we have reactive trips that if our operating basis earthquake is  
4 exceeded, then the plant will automatically shut down. Again the operating basis  
5 earthquake is some level, either 50 percent or less than the safe shut down  
6 earthquake.

7                   This is a picture basically of one of the -- of a seismic trip  
8 instrument. It's located at the base of the containment. It's about the size of a  
9 big shoe box, and if you go in the break room I happen to have one of the  
10 instruments that were taken out of the plant because it was no longer working.  
11 We had to replace it. But I do have one that you can just see. But essentially  
12 what you can see here is there's three instruments here -- accelerometers -- and  
13 they each measure one direction -- two horizontal and one vertical direction. So  
14 they measure the ground motion that the containment would see. And if two of  
15 these instruments indicate that the operating basis earthquake is exceeded, then  
16 the plant will automatically shut down. It sends a signal to a reactor protection  
17 system, piece of equipment that then starts the automatic shut down of the plant.

18                   Here is just to show you the amount of reinforcement that goes  
19 inside the containment. Right here in the center here is where the reactor vessel  
20 is placed. These walls here are around the reactor vessel is six feet thick. This  
21 is just a blow up view. You can kind of see the size of the reinforcement relative  
22 to the size of man.

23                   In this picture here, on the left here, you see the pipe support. This  
24 is for a main-steam line. This pipe is 40 inch in diameter. And as I mentioned  
25 previously, this is just to demonstrate that the pipe is not only designed to -- or

1 the pipe support is designed to keep the pipe intact, but also because of the  
2 postulated pipe break that we have to assume, we also have what we call a pipe  
3 whip restraint. And what this thing does then is to, if the pipe were to break, in a  
4 very unlikely event, the pipe would not whip around and hit anything else in the  
5 structure. And this is just a close-up view, again, of the pipe whip restraint.

6 These rods here, you see, are approximately two inch, two and a half inch in  
7 diameter. And then we have anchor boats that tie up this whole assembly to the  
8 concrete walls.

9           Again, here's another situation with a smaller pipe. This is about a  
10 12-inch pipe, and then we have a little pipe restraint here on the side. And then  
11 you can see the other pipe supports that are located here and going to bounce.  
12 We have pipe's numbers. What this does is -- pipe numbers allow the pipe to  
13 thermally move, but you have to get through an earthquake event occurs. The  
14 pipe's numbers lock up and then support the pipes. So that again, is to keep it  
15 integral.

16           This is again, to just show you an example of a pipe support that  
17 you might see in a nuclear plant. The pipe here is 28 inch in diameter. So you  
18 can see the size of the supports that are used to hold the pipe. And this is a 10-  
19 inch pipe, again with the support surrounding the pipe.

20           In terms of tanks, it's very important that they're anchored and  
21 stiffened at the base to prevent buckling. And so you can see that there's plates  
22 surrounding the base of the tank and then there's anchor boats to hold it to the  
23 foundation. And then finally, to show you the detail that we have in a nuclear  
24 plant -- this air tank here, on the left here, is basically about a quarter the size of  
25 the water tank that you see on the right. And there's half inch thick plates, straps

1 to weld it to a steel plate that is anchored to a concrete wall. And then at the  
2 base here there's a little table with a solid plate ring to support the bottom of the  
3 tank. Whereas, for your home, you would have basically a strap near the top and  
4 near the bottom that basically about a 1/16 of an inch or less. And that's just to  
5 show you the comparison of what we do when we design something for  
6 [unintelligible] plant.

7           So in conclusion, we must meet NRC seismic requirements,  
8 meaning we have to follow the regulations in terms of how we design the plant.  
9 Maximum site vibratory ground motions are used for seismic design. You know,  
10 there was talk about the probabilistic, but most of the existing plants have used  
11 the deterministic, and they were designed for the maximum site vibration.  
12 Seismic design process has conservatism which leads to large seismic margins  
13 and robust seismic capability. As you can see, along the way in our seismic  
14 design process, there's various margins that essentially accumulated as we  
15 reach the final product.

16           Finally, seismic monitoring instruments will cause the shutdown of  
17 the plant if the operating basis earthquake is exceeded. And this is true both for,  
18 as I mentioned, just having seismic instruments and then for the high seismic  
19 zones the two plants that actually will automatically shut down.

20           [applause]

21           DR. KAMMERER: Well, hello again. So during this session, I'll be  
22 talking about nuclear power plant licensing basis for seismic hazards. And  
23 although I'm standing before you, I really have to give all the credit for this talk to  
24 Dr. Cliff Munson, who's in the Office of New Reactors. He put together the  
25 presentation and was supposed to be here today, but unfortunately couldn't be

1 with us. So I'm hoping to be an acceptable stand-in for Dr. Munson. So all credit  
2 really goes to him for the presentation.

3           So as an overview, we're going to be talking about the NRC  
4 regulations, some information on citing safety reviews, information on operating  
5 reactors, risk assessment, what's happening with new reactors, and then a  
6 summary. So as you know, the NRC is -- really the job is of a regulator of  
7 nuclear safety. And so it's the NRC's responsibility to establish standards and  
8 regulations, to issue licenses for nuclear facilities and users of nuclear materials,  
9 to inspect facilities and users of nuclear materials to ensure compliance with  
10 regulations. These are areas in which we focus. Of course, the NRC operates  
11 under the Code of Federal Regulations. And it's towards the code that all of our  
12 efforts are geared. 10 CFR and several different parts are the portions which are  
13 related to the seismic review. So in the past, 10 CFR part 50 was used, and it's  
14 a two-step licensing process for construction permits and operating licenses.  
15 More recently, 10 CFR part 52 has been used, which is a new licensing process  
16 for combined license, design certification of the plants themselves, and early site  
17 permits. And both of those also incorporate the 10 CFR Part 100, which I believe  
18 you just saw some information on, which is reactor site criteria related to citing  
19 seismology and geology. And of course you can read these parts of the code of  
20 federal regulation for yourselves. In support of the code itself, of course the U.S.  
21 issues regulatory guidance and new regs, which also provide additional technical  
22 information on how we expect the 10 CFR to be met.

23           So nuclear power plant structures system and components  
24 important to safety are required to be able to withstand earthquakes, national  
25 phenomena, and such as the seismic shaking, and other events. And that's

1 something that we've been talking about all day, of course. One key element of  
2 that is what's called the safe shut down earthquake ground motion. And this is  
3 the vibratory ground motion which safety-related structures, systems and  
4 components must be designed. It's outlined in the Code of Federal Regulations  
5 and it's something to which we work. As I mentioned before, the safe shut down  
6 earthquake for current reactors typically use a deterministic analysis. And more  
7 recently then, SSC is determined by that uniform hazard response factor that I  
8 showed with an annual probability exceedance of 10 to the minus four with some  
9 additional enhancements. And we also look at the 10 to the minus five and 10 to  
10 the minus six ground motions and the way that changes.

11 So 10 CFR Part 100 requires that the SSC, that safe shut down  
12 earthquake, be determined through detailed characterization of the regional and  
13 local geology, seismology, geotechnical engineering, and of course, incorporated  
14 in this also is the geophysics, the geodesy, the GPS monitoring that we're seeing  
15 is also being incorporated -- really anything that helps us to get to that  
16 seismologic understanding. We also look at potential for surface deformation.

17 So, of course, in geology, some of the things we look at are  
18 geologic structures at a site and surrounding the site. Those are looked at in  
19 detail. There was a question earlier related to the Alquist Priolo Zone that was  
20 shown in the presentation, whether or not Diablo Canyon sits in one of those.  
21 The way that the NRC guidance is presented, the current NRC guidance actually  
22 requires very in depth study of that type at the sites and in different zones around  
23 the sites. That's undertaken for NPPs. And any structure that might cause a  
24 hazard, the site is identified and studied. And those are some of my colleagues  
25 in the New Reactors Office hard at work.

1           Of course, with seismology we have the earthquake catalogue and  
2 seismic source characterization. That includes looking at the earthquake history,  
3 the area surrounded the site. It's documented. We look at instrumental,  
4 historical, and geologic records, and that's combined with the other geologic and  
5 geophysical data sources. And I'd like to mention, there was some discussion of  
6 historic seismicity and paleoseismicity earlier in some of the talks. And that's an  
7 area of significant research in the Central and Eastern U.S. in addition to in  
8 California. And we're learning an awful lot about seismicity in the Central and  
9 Eastern U.S. through things like paleoliquifaction, and paleoseismicity studies.  
10 It's very, very interesting area of research that's going on.

11           So this is yet another plot showing ground motion prediction  
12 equations or attenuation relationships. And again, what it's looking at is for  
13 certain magnitude and distances what the shaking levels at the particular site  
14 are. And again, because there is natural alliatory variability, natural variability in  
15 the ground motions, we look at that assessment as well and incorporate that into  
16 our analyses.

17           So we saw this morning Professor Moss talking about geotechnical  
18 information, soil and rock properties in the site, on the site, that incorporates  
19 borings or rock sampling coring, geophysical measurements, standard  
20 penetration testing, cone penetration testing, a wide variety of site investigations,  
21 and of course, the associated laboratory testing, which is used for classification  
22 of the soils, understanding the engineering properties, and working towards our  
23 understanding of geological materials as a foundation material.

24           So, currently operating nuclear power plants generally establish the  
25 SSC using a deterministic approach. And as you heard earlier, that generally

1 looked at the maximum historical regional or local earthquakes -- either actual or  
2 predicted from the source characterization activities. The magnitude and  
3 distance maximum earthquakes were used to determine peak ground  
4 accelerations at nuclear power plant sites. And generally in the past, that PGA  
5 was anchored to a spectrum shape called the Red Guide 160 Spectrum [spelled  
6 phonetically]. It was developed in 1973 from 14 strong motion recordings. And  
7 this is the basis for a lot of plants in the U.S. in addition to internationally. This  
8 has been used extensively around the world for the design of NPPs.

9           Of course, since the licensing of these plants in the 1960s and '70s,  
10 earthquakes continued to occur and the NRC continued to look at the available  
11 information and to review the safety of plants. This particular figure shows the  
12 USGS Catalogue of Felt/Damaging Earthquakes from 1568 to 2004. And while  
13 many are focused in the west, as you can see, they are throughout the United  
14 States. And the red dots are the NPPs in the U.S.

15           So as was mentioned, the risk that comes from NPPs is not only  
16 the hazard, but it has to be tied to the protection, the robustness of the plant, the  
17 design of the plant to assure appropriate level design that gives adequate  
18 protection to prevent loss or damage. And that leads to an analysis of risk, the  
19 likelihood that that particular hazard will cause loss or damage. And I think this  
20 plot -- there was a question earlier about the Kashiwazaki-Kariwa nuclear plant.  
21 And I think this slide is really the heart of explaining what happened in  
22 Kashiwazaki and the lessons for the U.S. So it's probably appropriate after this  
23 talk that we go back to that question and address it.

24           So in the way that the NRC looks at hazard, it's not ever -- it never  
25 stands alone. It's looked at within a performance based framework, a risk-

1 informed framework to get to the ultimate performance of the plant. So in 1985,  
2 the NRC Commission issued a policy statement after looking at potential for  
3 severe accidents, and they concluded that the existing plants at that time posed  
4 no undue risk to the public health and safety. However, they recognized that  
5 valuable insights were gained from probabilistic risk assessment and PRAs,  
6 probabilistic risk assessments, have been a key element of understanding  
7 nuclear plant safety ever since. So in the late '80s and '90s, each licensee was  
8 requested to conduct individual plant examinations for internal events and also  
9 external events, what we call the IPEEE. And many of those used PRA.

10           So I wanted to take just a moment and talk about the components  
11 of what a seismic PRA actually is. So this slide sort of is a cartoon that's  
12 showing the various elements that we consider. Now up here at the top, we have  
13 our seismic hazard analysis. And so this is the load that we consider, the  
14 shaking levels with their different likelihoods of occurrence and frequencies of  
15 exceedance that goes into our PRA. But in addition, we have the elements  
16 related to design and the systems and the robustness.

17           So one of the elements that goes in is the fragility of individual  
18 components. So for any particular component, as you heard, there's a shake  
19 table testing that occurs, there's analyses that occur; and the equipment is  
20 qualified such that it remains safe and functional, operational during the SSC.  
21 But what we want to do is we want to look at those extreme events, the beyond  
22 design basis events as well. And look at the frequency of failure of individual  
23 components as a function of the shaking. Of course, you shake something hard  
24 enough and ultimately you can get it to fail. So that's shown for a particular  
25 component in this plot. It's basically a frequency of failure for a given level of



1 shaking.

2                   Now, of course, when you look at a risk of a nuclear plant --  
3 something that happened -- it's never the result of just one component. There's  
4 a whole series of bad things that have to happen. The plants are designed with a  
5 lot of robustness and margin and defense and depth. And so the next thing that  
6 happens is a systems analysis, which is this box here, which represents that  
7 chain of events that has to happen, all of the failure of different components  
8 during that earthquake. Often there's human failure in a number of these.

9                   And so what a systems analysis does is looks at all of the different  
10 possible ways, the different possible chains of events that could occur and lead  
11 to some sort of damage, or unacceptable performance at the plant, and takes  
12 that fragility for each of those components and combines it all together to say,  
13 "Okay, for a certain level of shaking then, what is the probability given the  
14 sensitivity of all of these different components, that all of this happens and we  
15 end up with that condition at the end?" So it's looking at all of these possible  
16 fault trees. And so it comes up with a whole list of them for any particular level of  
17 shaking. So you take that, all of those possible situations, and you have to  
18 convolve it with the seismic hazards. So what is the likelihood of different levels  
19 of shaking, and then what is the likelihood of some negative consequence given  
20 that level of shaking? That's the convolution here, and that gets you to, in this  
21 case, the main frequency of core damage, some parameter or some description  
22 of a negative event. So that's seismic PRA. And so that's how we get to an  
23 analysis of risk.

24                   So in the IPEEE study that was done in the '90s, it was  
25 implemented to evaluate beyond design basis events such as earthquake, fire,

1 and flooding. And for earthquakes, each licensee performed either a seismic  
2 PRA like I just described where they went through and found all of those possible  
3 sequences that would lead to core damage or they performed a seismic margin  
4 analysis depending on the particulars of the plant. The licensees evaluated  
5 structure and component fragilities to determine the margin beyond the safe shut  
6 down earthquake. A very important element of the seismic PRA is a walk down  
7 where you actually go through the plant and look at the actual physical condition  
8 of the plant. And so vulnerable equipment was also identified by walk downs.

9           So that was done in the '90s. But at the NRC, the reassessment of  
10 existing plants goes on all the time. And when new seismic -- excuse me, when  
11 new hazard significant information becomes available, the possible impact to  
12 safety of existing plants is reviewed. And we've discussed that here in San Luis  
13 Obispo many times. Safety significant information is acted upon by NRC staff  
14 regardless of licensing activities. So it's a continual process. It's not necessarily  
15 tied to relicensing. Of course, the IPEEE was undertaken in the '90s. But  
16 currently, the generic issue program is performing an assessment of new  
17 information for the Central and Eastern U.S. And that's a program which  
18 undertakes that type of work, and it's ongoing now.

19           Because of the move towards probabilistic risk assessment, and  
20 the fact that a fundamental input to that is the probabilistic hazard assessment,  
21 and also because of the benefits of PSHA in terms of characterization of  
22 uncertainty. During the 1980s, PSHA began replacing deterministic approach at  
23 the NRC. At about that time the seismic hazard models were developed for the  
24 Central and Eastern U.S. by Livermore and Apprie [spelled phonetically]. And  
25 currently, the NRC, DOE, Apprie with support for the USGS, assistance to the

1 PSGS, are doing new regional hazard model for the entire Central and Eastern  
2 U.S. And in addition, the U.S. Geological Survey began developing national  
3 seismic hazard maps, which you saw earlier which are on the basis of the  
4 building code.

5           So the current approach, 10 CFR 100.23 replaced Appendix A for  
6 NPP licensing in January 1997. This portion of the code specifies the use of  
7 probabilistic approach in order to quantify a certain decent seismic hazard. And  
8 Regulatory Guide 1.208, which was published in March of 2007, provides detail  
9 of guidance on development of site specific ground motion using probabilistic risk  
10 fixed approaches. And I should mention that the NRC's also developing  
11 additional guidance on how PSHA are undertaken.

12           So currently, as you're probably all aware, the NRC's reviewing  
13 new reactors designs and several new site applications. I'm not even sure how  
14 many are in-house at this point in time. So it's a big area for us. And this plot  
15 shows the new reactor sites which are currently being reviewed in house.

16           So in summary, NPPs are required to be able to withstand the  
17 effects of natural phenomena such as earthquakes. 10 CFR Part 100 requires  
18 that the safe shut down earthquake is determined through detailed  
19 characterization of seismic hazards. Seismic PRAs are used to verify the  
20 currently operating reactors have adequate safety margins. And NRC's  
21 regulations require licensees to reevaluate compliance with current licensing  
22 basis and new potentially safety significant, or risk or hazard significant issued  
23 are identified. Thank you.

24           [applause]

25           MR. BURTON: Torrey and Annie, thank you very much. Excellent

1 presentations. We're going to go into our question and answer period. Again, if  
2 you have a question, raise your hand. Bill or I will bring the mic to you --

3 MR. MAIER: Butch, I would like to provide one annoying reminder.

4 MR. BURTON: Okay, please do.

5 MR. MAIER: I'd like to remind folks if they're going ask questions  
6 that it would be best to ask questions from a generic sense. Mr. Yee is from  
7 Southern California, Edison. Dr. Kammerer is from the NRC. Tomorrow is all  
8 Diablo, all day long. Sounds like an ad for a radio station or something. But we  
9 will have a PGE expert on each of the three panels, and that would be the time to  
10 say, "Does Diablo do this?" But this is a time when Kashiwazaki-Kariwa is fair  
11 game, right? And any sort of the processes. So that being said --

12 MR. BURTON: All right, sounds good. And again, for those of you  
13 who have Diablo questions but won't be here tomorrow, please make sure you  
14 write them down with your contact information, and we'll make sure we get an  
15 answer to you. So with that, questions? Ah, my side.

16 MR. HUNT: Yeah, I noticed that you have -- oh, I'm sorry. My  
17 name is Gail Hunt [spelled phonetically]. I'm a geologist. You have a design  
18 spectra that's based on 14 celigraph records before 1973. That seems like pretty  
19 old data. I was wondering if the new data is still conservative and if the envelope  
20 still fits after all the data got in the last 40 years is added to be looked at.

21 DR. KAMMERER: Well, that Reg Guide 160 is definitely a classic  
22 at this point. It was developed based on the information at the time. And that  
23 relates to the licensing of the existing plants -- many of the existing plants. Of  
24 course, that's no longer used here in the U.S. Now we use a site-specific. It was  
25 used to provide the shape of the response spectrum and it was generally tied to

1 the PGA at a particular location. So currently the reviews that have been done,  
2 the reassessments that have been done, we've looked at the site-specific  
3 information in comparison with site specific-information.

4 MR. HUNT: I understand that, but it's still -- I was just wondering, is  
5 that a still conservative? I mean, if you plotted all the new data, would that still  
6 hold up for the existing plants? In other words, if you plotted the new data from  
7 1973 on and added it, would your enveloping spectra still be adequate for the  
8 design of the existing plants?

9 DR. KAMMERER: Well, you would write -- that was a very generic  
10 spectrum. Now, you wouldn't -- for every earthquake that's occurred since 1973,  
11 some of them have exceeded the -- it's the curve. Generally, they would fall  
12 under the -- the issue is the PGA would move. The shape is very broad. The  
13 shape is nice and tall and broad, so generally the answer is yes. But we just do it  
14 such a completely different way now. So when we do a comparison now or a  
15 review of the existing plants, we use site-specific information.

16 MR. HUNT: Okay, so you don't use that curve anymore?

17 DR. KAMMERER: No, sir. No, sir.

18 MR. HUNT: All right.

19 MR. MAIER: I'll ask June to repeat the question she had earlier  
20 today. You want a new one. Annie's all ready to answer your question.

21 FEMALE SPEAKER: I'll ask Annie the question if I can also ask  
22 this one of Mr. Yee. Okay, the first one I'll cut down. The Japanese plant shut  
23 down by an earthquake in 2007 was designed to withstand short, intense tremors  
24 that the builders had studied, and designed the plant based on those studies.  
25 Not the broad horizontal swaying that occurred with the 2007 earthquake. There

1 were numerous problems which I enumerated this morning. Some of them --  
2 there were 63 problems -- I didn't name all of them. Given that the Japanese  
3 regulators were incorrect in their calculations about earthquake movement and  
4 design of the plant, and we were also notified in the last session that even  
5 Parkview -- they underestimated the unknown for that, then can the NRC rely  
6 totally on the seismic studies being performed for Diablo to be accurate?

7 MR. MAIER: I guess, once again, maybe can they rely on design  
8 studies for any plant to be accurate? Is that a better way of asking it for --

9 FEMALE SPEAKER: Aren't there always --

10 MR. MAIER: -- for this panel.

11 FEMALE SPEAKER: -- [inaudible] unknowns that you cannot judge?

12 DR. KAMMERER: Well, Kashiwazaki-Kariwa is a very, very  
13 interesting and well-studied case, as you can imagine. It was really the first time  
14 that a plant exceeded its design basis and by a significant margin. And so as  
15 again, I get back to that slide and why I think it's very relevant is the risk of  
16 nuclear power plants come from two factors. They come from the hazard at the  
17 site and the design of the facility that leads to the ultimate societal risk. And you  
18 mentioned that there was some release into the Sea of Japan. It was actually a  
19 very, very small amount.

20 So we've been studying this even now for three years. And by the  
21 way, two of the reactors have now restarted. And one thing I think that's come  
22 out now that there's been a significant amount of work is the safety-related  
23 systems performed as design. There was no risk to the public during that event.  
24 It performed very well. Without a doubt, they underestimated the seismic hazard.  
25 And I think that really speaks to your point. You know, the design basis for the

1 earthquake was exceeded by two and a half times of the event they actually saw.

2           Now, I guess I would mention that when they perform the hazard at  
3 that site, they didn't do the offshore studies, such as are being done now. They  
4 weren't required. There was evidence that there was a fault there. It was not  
5 actively pursued by the utility, and it wasn't pushed by the regulator. And I think  
6 that's quite different from the situation we're seeing now where we're seeing fairly  
7 aggressive studies happening in the region to try and get to that. When we look  
8 at the fault that existed and that ruptured, and you use those ground motion  
9 prediction equations that I talked about several times that say, "Okay, for this  
10 magnitude and distance, the ground motions were predictable." And so I think  
11 one of the things that we've seen happen is actually a movement towards the  
12 approach that's used in the U.S. in terms of somewhat aggressive studies, rather  
13 aggressive studies, particularly in offshore environment and recognition of  
14 uncertainty.

15           One of the changes in the Japanese NPP regulations -- they  
16 changed the way that they actually assess hazard. And in their new regulations,  
17 they look at beyond design basis. Previously, they said the SSC will never be  
18 exceeded period. And now in their new regulations, there actually is a  
19 requirement that they consider that beyond design basis event and make sure  
20 there's not cliff edge effects.

21           And another thing that we've seen is a strong movement towards  
22 seismic PRA. I just, two weeks ago, was at an International Atomic Energy  
23 Agency meeting, IAEA meeting in Vienna, and what we saw the Japanese -- the  
24 technical support to the Japanese regulator presenting was unimaginable four  
25 years ago. I think that there's been a huge movement in opening of the

1 approaches that are being used. And it's very positive, and I see a lot of very  
2 good cooperation happening in the future. And so I think one really important  
3 thing is this once again shows us we must consider uncertainties. And the  
4 reason that those plants performed very well even though the design basis was  
5 so well exceeded was because of the margins that occurred.

6 Another interesting element of the Kashiwazaki experience is that  
7 right now one of the things that was presented two weeks ago was the results of  
8 something called the charisma benchmark. And what this is, the utility TEPCO  
9 provided a significant amount of information regarding the performance of the  
10 plant, elements of the plant, and allowed participants in this benchmark to use  
11 their own analysis tools -- their soil structure interaction modeling tools -- to take  
12 the basic information and blindly predict what they would have seen at the plant.  
13 And what we saw is that we actually -- our tools perform actually very well at  
14 being able to predict any kind of damage or the response of the plant. And so  
15 that's something that's very interesting. It's ongoing, and it's called the "charisma  
16 benchmark," and it's being performed through IAEA. And that's also providing a  
17 lot of very interesting information. Now one of the things that was in there was  
18 the sloshing of the pools. That's one of the things that are analyzed, that and  
19 also the tanks, the piping structure were all part of that analysis. And so that's  
20 providing us information on understanding how well out assessment tools are  
21 predicting these types of things.

22 And so then the other question is, given how the hazard analysis  
23 was not -- it was lacking, let's say, and the fact that, you know, we didn't see the  
24 Parkfield earthquake every 30 years, how much confidence can we have in the  
25 design and the information that's coming out? Well, again, as I said, there's a



1 significant amount of research that's happening here that didn't happen at that  
2 particular plant. And I think the key, once again, is really trying to wrap our  
3 heads around the uncertainty as well and making sure that we're considering all  
4 of that uncertainty and to not be surprised. And we don't expect it to be perfect,  
5 as you saw today. We're not going know everything perfectly. You never can  
6 with the Earth. Because even if you fully understood what happened in the past,  
7 there is a level of variability, and so the future is not -- you'll never know it  
8 perfectly. The important thing is to account for the uncertainty and to make sure  
9 that you incorporating that as we do the reviews and the design reviews and the  
10 seismic PRAs and that element. And I think that we have to understand that  
11 we're not going be perfect.

12 MR. MAIER: I'm glad you finished your presentation early. And  
13 per agreement, we'll let Dr. Kammerer's question, and June, I'll let you ask a  
14 question of Mr. Yee.

15 FEMALE SPEAKER: Okay, but I'd like to follow up on that one  
16 because you said, "It's not perfect." And certainly Katrina was not perfect either.  
17 And the reactors -- only two reactors are up, and it's three years after the  
18 earthquake. So there are still problems with that. And it also took PG&E Seismic  
19 Program 20 years to find the shoreline faults. So we've got several things there.

20 The question I have for Mr. Yee, though, is: when you use the  
21 shake tables in your simulations, do you use any corroded or aging equipment so  
22 you can analyze the effects on them? Because certainly, Diablo Canyon, we've  
23 seen all the corroded pipes and so forth that are below the surface. And I'm just  
24 wondering, do you use all new equipment when you do the shaking, or do you  
25 actually analyze the aging corroded pipes that exist in 20-year-old plants?

1 MR. MAIER: Good question.

2 MR. YEE: In the design of piping, when they do stress analysis,  
3 they actually consider a corrosion factor. So they include that already in their  
4 design. And so if they go out and check their piping and it's corroded beyond  
5 that point, then of course, it's not conforming any more. But during the design  
6 process, we do factor a corrosion factor especially in terms of piping. Now in  
7 terms of equipment, when we do shake table testing, we don't shake it just once,  
8 we shake it multiple times. So it essentially sees at least five or six earthquakes  
9 as part of that testing. So that kind of what we call seismic aging of the piece of  
10 equipment. And then there's also another program we call environmental  
11 qualification, which again would take into account the aging aspects of  
12 equipment and how they perform over their life.

13 MR. BURTON: I have one over here.

14 MR. O'CONNOR: Mike O'Conner [spelled phonetically], I'm a local.  
15 And Mr. Yee, the question about the shake table again. Is that done by an  
16 independent laboratory? And also, how big is the table? You know, what size  
17 equipment can be shook?

18 MR. YEE: Most plants -- I am going to speak -- San Onofre's  
19 unique and we do have our own shake table test, I mean, shake table. And that  
20 was out of necessity because of buying components. But for the most part, in  
21 general, all plants go to independent test labs to do the testing. And the size  
22 generally in the past, it's been -- electrical panels are probably the biggest thing  
23 that was actually tested, and those are usually in like about seven-and-a-half-feet  
24 tall, and maybe up to about four feet wide. And those are what gets tested on  
25 our table. Nowadays, there certainly are a large shake table tests, one that

1 comes to mind is one at University of California, San Diego, which can actually  
2 test buildings components full size.

3 MR. BURTON: Other questions?

4 MR. MAIER: Got one over here. From Jeff --

5 MR. BARD: Actually, I would like to defer if this gentleman does  
6 have -- [break in audio] -- otherwise, I'll proceed. Regarding the -- [break in  
7 audio] -- instruments, I certainly hope there's not only one. I think we all know in  
8 the Gulf of Mexico there was a device that failed. So if the seismic trip  
9 instrument fails, I hope that the general practice is to have a secondary backup.

10 MR. MAIER: Is that your question?

11 MR. BARD: No, actually, what happens if that fails? Is there a  
12 provision for manual shut down, and who would make that decision and how  
13 would they decide if the machine failed? And the other question is, what if you  
14 don't exceed the OBE, but there's a rupture somewhere? No one's going know  
15 there's a rupture. So it seems to me the OBE should be much less than 50  
16 percent. And finally, is shut down really the solution? I mean, if you have pools  
17 that even can slosh into the ocean, I don't see how you can say that the public  
18 was not endangered. I mean, what if somebody was surfing out there? I mean,  
19 so this is a group of connected questions.

20 MR. MAIER: Okay, first one was redundancy of the seismic trip?

21 MR. BARD: Yes, is there a redundancy or not? And what if there's  
22 a rupture?

23 MR. YEE: Okay, well, you asked how many instruments we have.  
24 And I'm going to just speak about San Onofre at this point, because I'm not  
25 familiar with Diablo Canyon's system. That black box you saw, basically we have

1 four instruments at the base of the containment, and they're located basically at  
2 90 degrees. So there's four equally spaced instruments. And we have what we  
3 call a two-out-of-four logic. And the reason for that is sometimes if somebody's  
4 down there doing maintenance -- if somebody kicks it, we don't want just one  
5 instrument to cause the plant to shut down. So it requires two out of the four to  
6 basically trip the panel automatically.

7 Now, you indicate, "Well, what if the instruments don't work?" By  
8 procedure, our operators still are required to check the level of the earthquake  
9 and then proceed. And their procedure is to do what's necessary, and that could  
10 be up to and including shutting down the plant. So they have to follow their  
11 procedure. We have to calculate, basically within four hours, what the level of  
12 the earthquake is and then proceed to shut down if the operating basis  
13 earthquake is exceeded.

14 MR. MAIER: And then the question of less than OBE -- less than  
15 operating basis earthquake -- plant does not automatically shut down, but there  
16 is a problem in a piping system somewhere.

17 MR. YEE: And then they would be responding based on whatever  
18 that system failure was. And if that included having to shut down the plant, then  
19 that's what they would do.

20 MR. MAIER: And the last question was --

21 MR. BARD: The other was, why does it have to exceed OBE in two  
22 directions? What if one direction is say 75 percent, far in excess of OBE, but in  
23 the other direction it's only at 49 percent of OBE? It doesn't sound like a logical  
24 design at all.

25 MR. YEE: It only has to exceed it in one direction.

1 MR. BARD: Thank you. He answered the question. I'm not quite  
2 sure he -- [break in audio] -- but he did answer the question.

3 MR. MAIER: The security concern -- what was that last one?

4 MR. BARD: Well, the safety concern -- I'm not satisfied that the  
5 safety concerns are fully addressed. But the question was answered.

6 MR. MAIER: Say that as a question, please.

7 MR. BARD: It was really a thank you, and I'm deferring to other  
8 people who may be waiting.

9 MR. MAIER: I appreciate that, Jeff. Thank you.

10 MR. BURTON: I got one.

11 MR. WEISMAN: Hi David Weisman. This is both a new reactors  
12 even though the fellow, Munson, is not here to talk about it -- is that his name?  
13 And because Kashiwazaki was at the same time, so let's see if we can combine  
14 this. Slide 15, Ms. Kammerer, probabilistic risk assessment, and Slide 17, same  
15 question. Since 1985, this has been something that's been asked for. And this  
16 would apply to San Onofre, too. Subsequent then to the 1985 statement --  
17 [break in audio] -- existing policy statement recognizes valuable insights from  
18 PRAs. Have SCE and PG&E done PRAs then subsequent to that statement?

19 MR. YEE: I can say that San Onofre, we have done our PRA for  
20 what she called the IPEEE. So that was done.

21 MR. WEISMAN: When was that done?

22 MR. YEE: 1995.

23 MR. WEISMAN: 1995. And for Pacific Gas and Electric?

24 MR. MAIER: All Diablo, all day.

25 [laughter]

1 MR. WEISMAN: All right, same slide -- her presentation, currently.  
2 Next would be, when you speak of an SSC and it speaks of a safe shut down  
3 earthquake -- and we referenced Kashiwazaki's as safely shutting down --  
4 question I have is, are the standards of building a reactor to meet an SSC, which  
5 assumes it shuts down safely, also assuming that the reactor is built with a  
6 robustness that once the earthquake has passed, the ground has stopped  
7 moving, the immediate danger is done, the structure should therefore also be  
8 able to generate electricity the next day. So you would say that the requirement  
9 of the SSC is simply it shuts down safely?

10 DR. KAMMERER: I think about how -- oh, here we go. Once an  
11 SSC is exceeded, a significant amount of work needs to happen before that plant  
12 would be allowed to operate again. That's why I think the years that it's taken to  
13 restart the plant to Kashiwazaki is not necessarily showing that there's huge  
14 problems. More that so much effort went into the review of that plant, testing,  
15 non-destructive testing. Of course, the regulatory environment there is very, very  
16 different. But if an SSC is exceeded, the level of effort to look at every part of  
17 that plant is such that it would not be operating the next day.

18 MR. WEISMAN: Okay, from a standpoint that if depending on it for  
19 my reliability, and generation, and shareholder perspective, the NRC standard of  
20 assuring safety in health is not [unintelligible] ensure commercial electric  
21 production or reliability of grid integrity as a result of a SSC event.

22 DR. KAMMERER: The NRC looks at safety.

23 MR. WEISMAN: All right, well then along those lines and since you  
24 mentioned new -- I got a lot of papers here -- new reactors and both  
25 Kashiwazaki. In 2008, NRC has document New Reg 1650, Addendum 3,

1 Question 19-1 is raised. For the lessons learned from Kashiwazaki nuclear plant,  
2 does the NRC have requirements to assess the anti-seismic ability of operating  
3 plants in the United States? And the answer is, "New reactor designs are  
4 expected to demonstrate an as-built plant has a level seismic margin of 1.67  
5 times the design basis. Even a 1.67 times the design basis event at high  
6 confidence in low probability failure," Page 127. The question, would Diablo  
7 Canyon meet that standard? Does it offer a design basis of 1.67 times the  
8 seismic margin?

9 DR. KAMMERER: We're going to be talking about Diablo Canyon  
10 tomorrow.

11 MR. WEISMAN: No, no, but this is in relation to Kashiwazaki. That  
12 was the --

13 DR. KAMMERER: No, you just -- that wasn't in relationship to  
14 Kashiwazaki.

15 MR. WEISMAN: It's the same paragraph. It's the answer in the  
16 NRC's own document to the question that was asked about Kashiwazaki. And  
17 I'm just saying if that's the answers that -- what is the lesson learned? That a  
18 plant must be built to 1.7 times the design basis confidence.

19 DR. KAMMERER: Well, that's not lessons learned from  
20 Kashiwazaki. That requirement comes from NRC's own work previously. The  
21 requirement for 1.67 is an NRC regulation. It's unrelated to Kashiwazaki. The  
22 work that was done in Kashiwazaki to look at the margin and understand what  
23 happened in that plant is a different type of work that was happening. Now the  
24 Apprie documents in U.S. sort of approach has played significantly into that. But  
25 I don't -- the question relates to Diablo Canyon.

1 MR. WEISMAN: All right, well if that's how it's gonna be then I'll  
2 save the ACRS testimony from 2008, again, regarding new reactor standards.  
3 But because they mentioned Diablo Canyon deep into the document, I guess I'll  
4 have to wait for that. So let's go back to Japan then, besides Kashiwazaki, has  
5 any investigation --

6 MR. BURTON: David?

7 MR. WEISMAN: -- has any other investigation been done of over  
8 year long outages caused by the earthquakes at the plants in Onagawa and  
9 Hamaoka? I'm sorry, did you not catch that? In addition to Kashiwazaki, has any  
10 evidence -- has any research been done on the year-long outages that were  
11 caused by earthquakes at Hamaoka and Onogawa?

12 DR. KAMMERER: Yeah, a significant amount of research has  
13 actually been done in Japan. In fact, when the Kashiwazaki earthquake  
14 happened, Japan was already in the process and, in fact, already had changed  
15 its regulatory guidance related to seismic hazard as a result of earlier  
16 earthquakes at NPPs in Japan, in which seismic events occurred. And so a  
17 significant amount of work has happened in Japan looking at those events. In  
18 fact, there was already an extra-budgetary program that was started at the  
19 International Atomic Energy Agency to look at seismic reevaluation of existing  
20 plants. And because the Japanese wanted to make the most of those  
21 experiences, and to pull in international expertise, they actually had initiated an  
22 extra-budgetary program research program at IAEA, even before Kashiwazaki  
23 occurred. So a significant amount of work has been done in Japan looking at the  
24 various events. And, in fact, they completely changed their regulatory guidance,  
25 and were in process of starting the review before Kashiwazaki happened.



1 MR. MAIER: I've got a question over here from Jane.

2 MS. SWANSON: Yeah, Jane Swanson [spelled phonetically], I  
3 have questions about the spent fuel pools at Diablo Canyon -- in general, and the  
4 reason --

5 [laughter]

6 -- no, it works in general. I'm going on Mr. Yee's presentation and  
7 Diablo entered my mind because of highly dense storage of spent fuel there. So  
8 it's on my mind. But under the seismic classifications category one, safety-  
9 related, you know, you gave examples and I know they were just a few  
10 examples. I'm just hoping you're gonna tell me that the spent fuel pools are  
11 considered safety equipment in category one.

12 MR. YEE: Yes, spent fuel is considered seismic category I.

13 MS. SWANSON: Okay, that makes me feel better. And then, if  
14 you would like to say a word about in general, how those spent fuel pools are  
15 tested regarding their ability to withstand a major earthquake, I'd be interested in  
16 that.

17 MR. MAIER: Thank you, Jane.

18 MR. YEE: Spent fuel pools are designed basically like the structure  
19 -- we consider the forces from the spent fuel rocks. And we also consider the  
20 hydrodynamic and hydrostatic forces from the water in the pool. So they are --  
21 basically, most pools are reinforced concrete walls and so that the forces from  
22 the earthquake and again, normal accident loads. In the case of spent fuel  
23 pools, we also consider the high temperatures that could occur due to loss of  
24 cooling. And all that's then factored into the structural design of the concrete wall  
25 that's around the spent fuel.

1 MR. BURTON: Other questions?

2 MS. BECKER: Rochelle Becker, Alliance for Nuclear  
3 Responsibility. I was wondering if either one of you know how many studies that  
4 included lessons learned from the KK earthquake you're aware of? Have the  
5 NRC done any? Has [unintelligible] done any? Has SCE done any? I just want  
6 the number of lessons learned, either from the KK quake or other Japanese  
7 quakes, that people in California could have learned from.

8 MR. BURTON: Can I piggyback on that? Can you talk in general  
9 about how we use international information, how we share it, and what we do  
10 with it? You know, we're focusing a lot on the reactors in Japan. But there are  
11 reactors all over the world. How do -- in general, how do we share that  
12 information? And when we find some information that's significant, what we do  
13 with it?

14 DR. KAMMERER: Okay, well, there's a number of studies that  
15 have happened. In the NRC -- unfortunately the studies are non-public because  
16 we were provided proprietary and sensitive information. But it's a little hard to  
17 separate them out into a number of lessons learned because sometimes, you  
18 know, they're more all encompassing. Sometimes, you know, depends on how  
19 you break down the specific lessons. So, I mean, definitely it's something we've  
20 been looking at in depth for a very long time.

21 In terms of how -- and you're right, there have been additional  
22 NPPs which have, you know, gone through different external events, not only  
23 seismic hazard but also things like tsunami. Currently, most of the international -  
24 - of course, the NRC tracks this information, but much of the international  
25 experience is actually currently held in a new international seismic safety center

1 at IAEA. It was just initiated with Japanese support in July of last year. And, in  
2 fact, has really gotten into full swing with the end of some extra-budgetary  
3 research projects which are ended and now going to this new international  
4 seismic safety center. And it was developed in response to the Kashiwazaki  
5 earthquake, and also in response to the Indian Ocean Tsunami as a clearing  
6 house of information and research, because one really didn't exist. We sort of --  
7 the international community came together when there were lessons learned to  
8 be had and disbanded. So the International Seismic Safety Center is now a  
9 permanent sort of clearing house for information for cooperative research. It's a  
10 really, a very positive -- one of the positive outcomes of the Kashiwazaki  
11 experience. And so as part of that, the IEAE has developed the International  
12 Experience Database which everyone puts their data into and which then is  
13 shared.

14           As part of that, there have also been 10 topical areas, which have  
15 been identified as areas of mutual interest among the international nuclear  
16 community; and a lot of those folks around seismic hazard. Working area  
17 number one is seismic hazard analysis and looking at uncertainties, looking at  
18 different elements of that. Working area three is seismic PRA. And so that's  
19 really now the focus of how external events -- it's called the Seismic Safety  
20 Center, but it's really all external events -- moving forward are going to have a  
21 more robust framework. And so that's going to be sort of the focus moving  
22 forward with annually a meeting to identify areas of active research and share  
23 information as well as a number of workshops that are gonna be happening over  
24 time throughout -- depending on when research information comes out.

25           And in fact, there are gonna be a major workshop which is

1 happening in Kashiwazaki in November to open a new research center in the  
2 Niigata Institute of Technology, which JNES -- which is the technical arm  
3 supporting the Japanese regulator has sponsored. And so significant amount of  
4 research in terms of seismic hazard in Japan will be happening at that research  
5 center. So there's an international forum which is gonna be happening in  
6 November.

7 MR. BURTON: One second, one second. Make sure everybody  
8 can hear you.

9 DR. KAMMERER: Well, you can go to the workshop in Niigata.

10 MS. SWANSON: No, no, IAEA website where you're storing all this  
11 information, you just told me that the NRC's is confidential. Is the IAEA's  
12 confidential, too?

13 DR. KAMMERER: I'm not sure. I would assume so. Well, at least  
14 you would have to be contributing data.

15 MR. BURTON: I think we -- do you want to speak to that? We may  
16 have an answer for you here.

17 MR. MARKLEY: I'm Mike Markley from NRC headquarters. The  
18 IAEA information itself is proprietary, and it's handled that way. That's the  
19 reason that the information is shared with us in that manner. Now, we do a lot of  
20 sharing back with them, but I will say with regard to the Japanese event, the  
21 industry's also issued a fairly comprehensive SER on that. So, I mean, the  
22 industry's communicating and doing things as well. It's not just the NRC that's  
23 involved in all of this. There's a lot of players in the process. But the initial IAEA  
24 reports on this are considered proprietary from all countries when they're  
25 submitted. Now, if they're released later with the permission of those countries,

1 because that's the reason it's shared that way, then they have to release it.

2 MR. MAIER: Butch, is there still a generic question about it? Or  
3 did you want to, you know, ask about the generic process? I hope it's a question  
4 because you're gonna be on a panel tomorrow, and this is double dipping if  
5 you're gonna say something.

6 MALE SPEAKER: No, I just wanted to make sure that you  
7 understand the NRC has a very robust process of looking at operating  
8 experience. There are 24, 25 different groups to which this kinds of information  
9 is circulated as soon as something important happens. And the leaders of these  
10 groups recommend what action needs to be taken, and it is followed up through  
11 all the nuclear power plants if it is appropriate. And I don't want to get into any  
12 kind of details, but just wanted to make sure you understood that operating  
13 experience is supposed to have been considered through an independent office  
14 of operating experience. It is now subsumed into Office of Nuclear Reactor  
15 Regulation, and the events of significant nature are immediately looked at.

16 MR. MAIER: Thank you. We've got Judith if there's nobody on  
17 your side. We've got Judith over here if there's nobody on your side.

18 MR. BURTON: Doesn't look like it.

19 MR. MAIER: Okay, Judith.

20 FEMALE SPEAKER: Just one for Mr. Yee. About SONGS, I think  
21 the first reactor there was retired, and it's still on site isn't it? Or did they get it  
22 away? They had a lot of trouble loading it or something, as I remember.

23 MR. YEE: Yes, the unit one reactor vessel is still on site.

24 MR. MAIER: Is it seismic?

25 FEMALE SPEAKER: The big red canisters or tanks -- there must

1 be about 30, or maybe 25 to 30 of them on site there, and I've always wondered  
2 as I passed by train if that's the storage for the spent fuel. What's in those red --  
3 big red canister-type tanks?

4 MR. YEE: Yes, we do store spent fuel -- dry storage, is that what  
5 you're --

6 FEMALE SPEAKER: Dry.

7 MR. YEE: Dry storage of the spent fuel.

8 FEMALE SPEAKER: Thank you.

9 MR. BURTON: Any other questions? I thought I had seen a hand  
10 over on Bill's side before, no? I guess I was mistaken. Okay, if there are no  
11 more questions, we're gonna go into our closing, and I'm going to ask Roy  
12 Caniano to close us out.

13 MR. CANIANO: Well, first of all, I want to thank everybody here  
14 today for their participation in the workshop we had; in particular, each of the  
15 panel members, both of our facilitators, and the moderators for each of the  
16 panels. When you take a look at all of the panels that we had today, we had four  
17 of them, a lot of information was provided, and we actually finished on time. So I  
18 appreciate the efforts on everyone.

19 When reflecting on my opening remarks from this morning, I said  
20 one of our goals today was really to provide information and educate. I can tell  
21 you I learned more today about seismology than I did -- I know more now than I  
22 did before this morning walking in here, and just talking to some of the audience  
23 here, I think that's the same reaction they have as well. So I appreciate  
24 everyone's participation, high level of professionalism. We established some  
25 ground rules this morning, and everyone complied with the ground rules. And I

1 think that facilitated the success to this meeting today.

2           This morning there was a statement made. It was associated with  
3 the timing of the workshop. And I do want to apologize if there's any  
4 inconvenience that we're putting on anyone tomorrow for those folks that are not  
5 able to attend the workshop for tomorrow. I know we've mentioned a couple of  
6 times that we are videoing this. And again, there's cards that are available. I  
7 urge each of you, if you have questions for the panel members tomorrow that  
8 you're thinking of now, please provide them to any of the facilitators tonight  
9 before you leave. I know it's not the same as being here in person. But again, I  
10 think it is an opportunity to take a look at the video in a week or two.

11           So with that again, I thank everyone for their participation today.  
12 And we will see everybody in the morning at about 8:00. Bill, I think you have  
13 some logistics.

14           MR. MAIER: Of course, I'd like to thank everybody except for the  
15 facilitators. They were a real pain.

16           [laughter]

17           But I was asked to make an announcement -- actually, a couple of  
18 announcements. If you have one of these plastic badges and you're not planning  
19 to come back tomorrow, or are unable to come back tomorrow, we've got a little  
20 box out on the tables as you go out, if you'd like to drop it there. We will recycle  
21 these. If you are coming back tomorrow, feel free to take your badge with you  
22 and then we can collect it at the end of the day tomorrow.

23           Also, if you're not coming back tomorrow due to whatever reason, if  
24 you would please take the time -- and since we're finishing up a little bit early,  
25 take the time to fill out one of those public meeting feedback forms and get it to

1 any of the NRC folks or you can leave it up here -- I guess on the front table if  
2 you don't, you know, know who to give it to. If you thought it was a horrible first  
3 day experience, we want to know. If you thought it was a great first day  
4 experience, Roy wants to take the credit for it.

5           Also, if anybody has any questions that are based on the topics that  
6 we had today that you were not able to ask, or you felt uncomfortable standing  
7 up to ask, we haven't gotten any cards that have questions and contact  
8 information on it. If you would please put your contact information, e-mail, phone  
9 number, legibly on the card with your question, we'll try to get an answer to you.  
10 And with that, we will start at 8:00 tomorrow.

11           MR. CANIANO: For the panel members, if you could stick around  
12 just for five, 10 minutes and maybe convene in the room next door. Appreciate it,  
13 thanks.

14

15                           [Whereupon, the proceedings were concluded]