1 DR. LUK: Yes. At Sandia Lab we have a
2 common practice for anyone who is involved in doing
3 the dynamic modeling for the finite elements
4 methodology. That person is required at least a few
5 years of experience before they can actually touch
6 this area, mainly because the outcome of the dynamic
7 modeling of a finite elements model is just as good as
8 what you put in. So if a person is not real
9 experienced in this class of technical problems, the
10 outcome is highly questionable. So it is a basic
11 requirement, as we practice at Sandia National Lab,
12 that the analysts are required to have a few years of
13 experience in this area.
14 MR. TURK: You have read Dr. Bartlett's
15 rebuttal testimony in response to your report of March
16 31? That's the written transcript that I believe you
17 have a copy of on the table in front of you.
18 DR. LUK: Yes, sir.
19 MR. TURK: And you heard his oral
20 testimony today, correct?
21 DR. LUK: Yes, sir.
22 MR. TURK: Do you believe that Dr.
23 Bartlett has a good understanding of how you
24 constructed your model with respect to the interfaces
25 between different portions of the model; i.e., the

1 soil, the cement-treated soil, and the pad?

2 DR. LUK: I received through email a

3 transcript of the testimony from your last week, and

4 of course this morning I was physically present to

5 witness some of the communication between the witness

6 and the lawyers. I basically have identified quite a

7 few fundamental problems.

8 MR. TURK: When you say, "fundamental

9 problems," do you mean in the concerns that Dr.

10 Bartlett raises about your report?

11 DR. LUK: Yes, sir.

12 MR. TURK: Do you believe that he properly

13 understands how you modeled the interface between

14 these different structural components, the pad, CTS,

15 and soils?

16 DR. LUK: It is my understanding there is

17 quite a bit of misconception and misunderstanding as

18 to what happens at the interface. If you don't mind,

19 I will try to elaborate a little bit to try to clear

20 the matter.

21 The first thing I observed as a problem is

22 that the so-called coefficient of friction at the

23 interface between two bodies is an estimate of the

24 friction in the systems of one body in motion with

25 respect to the other, basically, fitting Coulomb's Law

1 of Friction.

2 Now that is a law that has been expressed

3 many years ago, and all new students, even at a

4 freshman level, have been exposed to that.

5 MR. TURK: May I ask you, you refer to

6 Coulomb's Law of Friction --

7 DR. LUK: Yes, sir.

8 MR. TURK: Is that the equation f equals

9 mu N?

10 DR. LUK: Yes, sir.

11 MR. TURK: Go ahead.

12 DR. LUK: Also, in particular, there is a

13 coefficient of friction; in particular, the Coulomb's

14 Law of Friction is a description of the frictional

15 resistance at the interface, as material properties at

16 the interface. It's also a parameter that has depends

17 on the material, but more on the surface condition of

18 the two bodies.

19 MR. TURK: Now you heard Dr. Bartlett

20 refer to the Mohr-Coulomb theory of failure this

21 morning?

22 DR. LUK: Yes, sir.

23 MR. TURK: Right?

24 DR. LUK: Yes.

25 MR. TURK: In your mind, is that a proper

1 equation to use in attempting to model the interface
2 between the pads and the CTS or the CTS and the soil?
3 For reference, let me note again, if I say "CTS,"
4 that's an abbreviation of cement-treated soils, which
5 I may use in order to speed up my delivery of my
6 questions. "FEA", if I use that, that would be finite
7 element analysis. Okay?
8 Do you need my question repeated?
9 DR. LUK: No. This is my understanding of
10 Coulomb's theory of failure for soil.
11 MR. TURK: May we go off the record for a
12 moment?
13 (Whereupon, the foregoing matter went off
14 the record briefly and went back on the record.)
15 MR. TURK: Just so we're fresh, could you
16 repeat the question that I asked (speaking to the
17 court reporter)?
18 (Whereupon, the pending question was
19 played back.)
20 DR. LUK: The answer is no. The reason is
21 that the Mohr-Coulomb theory of failure for soil is
22 prescribed in principle to the failed mechanism in
23 soil material. At the interface we are not in the
24 soil. We are just at the interface. The coefficient
25 of friction that we prescribe only occurs at the

1 interface.

2 MR. TURK: Now when you say, "the

3 interface," are you describing a space that exists

4 between two bodies?

5 DR. LUK: Yes. The qualitative answer to

6 that is that in the physical world that we are in,

7 when we deal with physical world at the interface,

8 there is no material, but there is ongoing effort in

9 academia, in industry, and in National Labs, of people

10 trying to understand the phenomena. They are

11 identified as tripology. That means when you really

12 go to the manual space, there is material at the

13 interface, but in all the physical world for the

14 finite elements model we do not incorporate that. So

15 when we prescribe a coefficient of friction, it is

16 nothing more than a prescription of the frictional

17 resistance offered by one body in reference to the

18 other.

19 MR. TURK: Now you said, "When we use

20 finite element analysis modeling." Are you referring

21 only to yourself or are you referring more generally

22 to the body of experts who do finite element modeling?

23 DR. LUK: I think I made reference to the

24 current practice for engineers and analysts working

25 with the dynamic models using finite analysis

1 methodology.

2 MR. TURK: You are a graduate of

3 Northwestern University?

4 DR. LUK: Yes, sir.

5 MR. TURK: You have a Ph.D. in structural

6 mechanics?

7 DR. LUK: Yes.

8 MR. TURK: And is that also applied --

9 what is the exact discipline that you received your

10 Ph.D. in?

11 DR. LUK: Oh, it is called theoretical and

12 applied mechanics.

13 MR. TURK: Are you aware whether

14 Northwestern University has any studies underway at

15 present with respect to the nanospace that you just

16 described?

17 DR. LUK: Yes. I was informed by my

18 thesis advisor that he was part of the team; they were

19 granted multimillion dollars for the next ten years to

20 study this phenomena at the interface, which they call

21 the tripology in nanospace.

22 MR. TURK: Just so the record is clear,

23 when you say, "nanospace," could you give us some

24 sense of what that means?

25 DR. LUK: Well, "nano" by definition is 10

1 to the minus 9th order. So it is very, very small.

2 MR. TURK: When you use a coefficient of

3 friction on mu equal to 1.0, were you attempting to

4 portray the soil properties either in the soil below

5 the CTS or the material properties of the CTS or the

6 material properties of the pad?

7 DR. LUK: When we use the coefficient of

8 friction, and in this case, for example, it goes to

9 1.0, it is just a prescription of the amount of

10 frictional resistance at the interface. They are not

11 related to the material properties, either in the pad

12 or in the cement-treated soil.

13 MR. TURK: For that reason, do you believe

14 that Dr. Bartlett is incorrect in his statement that

15 you were wrong in how you modeled the interface in

16 that you did not reflect the soil properties or the

17 CTS material properties?

18 DR. LUK: Correct.

19 MR. TURK: He would be wrong?

20 DR. LUK: Yes.

21 MR. TURK: The Coulomb Law of Friction

22 that you discussed, that is the equation of f equals

23 mu N. Is that typically the coefficient of friction

24 that is used to describe mu when people perform finite

25 element analyses and dynamic models, as you have done

1 here?

2 DR. LUK: Yes. People use Coulomb's Law

3 in finite elements methods, particularly use that in

4 the simple calculations.. They do it in the static

5 analysis. Yes, that formula has been used very, very

6 often.

7 MR. TURK: Is it your view that that is

8 the correct way for you to have modeled mu in your

9 work here with respect to the PFS facility?

10 DR. LUK: Can you rephrase the question?

11 MR. TURK: Yes, perhaps I misspoke. When

12 you were defining mu1 or mu2 here, were you using this

13 equation of f equals mu N?

14 DR. LUK: Yes.

15 MR. TURK: Do you believe that is the

16 proper way in which to model the interface between the

17 soils and the CTS and the interface between the CTS

18 and the pad?

19 DR. LUK: Yes.

20 MR. TURK: And I should say also the

21 interface between the pads and the casks, the mu1?

22 DR. LUK: Yes.

23 MR. TURK: Dr. Bartlett indicated that the

24 design intent for the PFS facility is that there

25 should be no sliding between the pad and the CTS or

1 the CTS and the soil. You heard that part of his
2 testimony?
3 DR. LUK: Yes.
4 MR. TURK: And you recognize that as the
5 design intent that PFS has formulated and --
6 DR. LUK: Yes.
7 MR. TURK: -- is relying on here? Do you
8 believe that your model appropriately reflects the
9 intent that there be no sliding between the pad and
10 the CTS and the CTS and the soil?
11 DR. LUK: The modeling approach that we
12 follow is as follows: It is recommended practice,
13 and, as a matter of fact, it is actually a required
14 practice at Sandia, that we make the assumptions in a
15 pre-analysis in developing the finite elements model.
16 We allowed movements to take place at the interface.
17 It is only the pre-test analysis evaluations. When we
18 get the analysis results, we look in particular at
19 those results related to the assumptions that we made.
20 For this case, we are trying to find out,
21 is there any relative displacement between the bottom
22 of the pad and the top of the cement-treated soil?
23 Our analysis results indicate that, yes, there is
24 displacement, but the magnitude of displacement
25 throughout the total history of the seismic event is

1 very, very small. We actually pulled out the results
2 for one of the worst cases, for the 10,000-years-
3 return seismic event. So we plot more than one
4 location. The result indicated that the maximum that
5 happens in a very, very short duration ranges between
6 .06 inch and .1 inch.
7 In that sense, we actually go through the
8 modeling. We allow it to slide, but, as it indicated
9 in the results, there is not much sliding at all. So
10 in that sense we confirmed the design intent.
11 MR. TURK: Let me back up a little bit and
12 ask you about a few of the statements you just made.
13 First of all, you indicated that you have plotted it
14 out for the 10,000-year case. You have also plotted
15 out the 2,000-year case, haven't you?
16 DR. LUK: Yes.
17 MR. TURK: Okay, let's look at the more
18 extreme case, 10,000 years.
19 DR. LUK: Yes.
20 MR. TURK: Would that bound the amount the
21 amount of displacement that would be found between the
22 pad and the CTS for the 2,000-year case?
23 DR. LUK: Yes.
24 MR. TURK: Also, it would bound the amount
25 of displacement between the CTS and the soil for the

1 2,000-year case, correct?

2 DR. LUK: Yes.

3 MR. TURK: In that respect, that is where

4 you found .06, or I'm sorry, a range of between .06

5 inches and .1 inches of displacement? That was the

6 10,000-year case?

7 DR. LUK: Yes, sir.

8 MR. TURK: For the 2,000-year case, would

9 the amounts of displacement be less than what was

10 reflected for the 10,000-year case?

11 DR. LUK: Yes.

12 MR. TURK: Can you give us an

13 approximation of how much?

14 DR. LUK: Well, based on the amplitude

15 between the 2,000-years-return and the 10,000-years-

16 return seismic events, the reductions would probably

17 be by a factor of two.

18 MR. TURK: So, in a general sense, you

19 would find roughly between .03 inches and .05 inches

20 of pad displacement on the CTS for the 2,000-year

21 case?

22 DR. LUK: Yes, in a general sense.

23 MR. TURK: One other statement you made

24 was that this was a very short time increment at

25 which that displacement was found. Do you recall that

1 statement or something along that line?

2 DR. LUK: Yes.

3 MR. TURK: What was the very small

4 increment that you are talking about?

5 DR. LUK: Here, if you don't mind me, I

6 will elaborate a little bit. In our modeling we

7 choose to use Abaqus which is commercially available

8 codes. They have substantial background in the QA

9 procedures, but we choose to use the explicit version

10 of the Abaqus code. In that, the time increment for

11 the calculations are calculated within the code, and

12 for that the delta T, the time increment, is four

13 times ten to the minus five seconds.

14 For that reason, some higher response in

15 terms of displacement, for example, and sometimes in

16 terms of the accelerations occur because of the

17 precise nature of the small delta T that was intrinsic

18 to the explicit calculations. But that does not mean

19 that it will have much effect in the structural

20 response calculations.

21 MR. TURK: Just so I understand correctly,

22 and I am going to distribute in a moment some

23 materials that you have prepared for distribution

24 today, when you say that you found for the 10,000-year

25 case a range of between .06 and .1 inch of

1 displacement, that displacement occurred for periods
2 of time of four times ten to the minus five seconds?
3 DR. LUK: I think the durations for those
4 high, relative displacements occurred in the
5 neighborhood of the order of magnitude of the delta T.
6 But even if we say a hundred times of the delta T, it
7 is still only of the order of ten to the minus -- four
8 times ten to the minus third power. Even in that
9 sense, it is still very, very small durations.
10 MR. TURK: Your Honor, I would like to
11 distribute at this time and ask to have marked for
12 identification Staff Exhibit YY.
13 For the record, let me indicate that what
14 I have distributed, or asked Mr. O'Neill to
15 distribute, and he's kindly obliged, is a cover sheet
16 that bears a handwritten figure and table, followed by
17 five pages of color graphs.
18 [Whereupon, the above-referred-
19 to document was marked as Staff
20 Exhibit YY for identification.]
21 MR. TURK: Dr. Luk, do you recognize this
22 document?
23 DR. LUK: Yes.
24 MR. TURK: Could you explain, first of
25 all, what is the cover page which bears the hand-drawn

1 figure and table?

2 DR. LUK: This sketch is the top view, if

3 you look down at the concrete pad. The circle

4 indicates the location of the cask on the pad.

5 MR. TURK: That is a cask, one cask?

6 DR. LUK: One cask.

7 MR. TURK: And that is just put in here as

8 a demonstration of the scale, a rough approximation of

9 the scale between the cask and the pad?

10 DR. LUK: Or try to find out if there is

11 any differences or how sensitive are the plots of the

12 results in reference to the location of the cask on

13 the pad.

14 MR. TURK: Okay. What is the table that

15 appears below the figure?

16 DR. LUK: Well, we try to demonstrate for

17 the five selected nodes which are identified as A, F,

18 G, H, I, for those five locations, the relative

19 displacement of the bottom of the pad with respect to

20 the top surface of cement-treated soil. The point A,

21 in particular, the point A is the center of the pad.

22 MR. TURK: Just for clarification, I

23 notice two of the columns in this table are labeled

24 "soil top." Should that, instead, really say,

25 "cement-treated soil top"?

1 DR. LUK: Yes.

2 MR. TURK: I would ask that we keep that
3 in mind as we discuss this. In fact, that is the top
4 of the CTS directly beneath the pad, correct?

5 DR. LUK: Yes.

6 MR. TURK: And that is the third and the
7 fifth columns in the table. Then in the table you
8 indicate for each point what appears to be different
9 node numbers, is that correct?

10 DR. LUK: Yes.

11 MR. TURK: For instance, next to point A
12 you have the node at the bottom of the pad is Node No.
13 11240, and the next column you indicate that the node
14 at the top of the cement-treated soil at that location
15 is Node No. 131150, is that correct?

16 DR. LUK: Yes.

17 MR. TURK: Okay. Incidentally, just by
18 looking at these numbers, it would appear to me that
19 perhaps there were more nodes involved in your model
20 than you had indicated previously in your testimony.
21 I believe you had indicated previously that there was
22 something on the order of 5,000 nodes in your finite
23 analysis model of the PFS site. Did you, in fact,
24 have more notes than that?

25 DR. LUK: I think for the site-specific

1 model for the Private Fuel Storage, our model is a lot
2 more complicated than the other models that we used
3 for the two other sites, simply because of the
4 presence of cement-treated soil. Yes, it is much,
5 much bigger.
6 MR. TURK: You say the other two sites --
7 I'm sorry.
8 DR. LUK: Yes.
9 MR. TURK: When you say that the model was
10 more complicated than the models for the other two
11 sites, that is a reference to Sanofrey and Hatch?
12 DR. LUK: Yes, sir.
13 MR. TURK: Do you recall roughly how many
14 nodes you used in your PFS FEA model, approximation?
15 DR. LUK: I think it is close to 200,000
16 nodes.
17 MR. TURK: Okay, let's turn, if we will,
18 to the very next page, and just so we get a proper
19 understanding of what this reflects, the caption at
20 the top of this chart reads, "Relative displacements
21 between concrete pad and soil cement, point A, located
22 at center of pad. PFS 10,000-year-return seismic
23 event, lower-bound soil profile data." Do you see
24 that caption?
25 DR. LUK: Yes, sir.

1 MR. TURK: Just so we are clear, here
2 where the phrase "soil cement" is used, in fact, that
3 is the cement-treated soil?
4 DR. LUK: Yes.
5 MR. TURK: By the way, look at the other
6 graphs that follow. The next four pages of this
7 exhibit also use the word "soil cement." In each case
8 should that really say, "cement-treated soil"?
9 DR. LUK: In our report we used "soil
10 cement," but it is equivalent to cement-treated soil.
11 MR. TURK: Okay, but we are not talking
12 about the soil cement next to the pads here; we are
13 talking about the CTS that is below the pads, correct?
14 DR. LUK: Yes, sir.
15 MR. TURK: Okay. Now in this first chart
16 that appears, you indicate that is point A located at
17 the center of the pad. If we want to see where that
18 is, we would look at the figure on the first page of
19 the exhibit; we would find point A dead center of the
20 pad, correct? Approximately dead center?
21 DR. LUK: Yes.
22 MR. TURK: Now you show here a plot of
23 displacement in the U1 and U2 directions. Are those
24 the two horizontal directions?
25 DR. LUK: Yes.

1 MR. TURK: Okay. So it would be
2 longitudinal and latitudinal direction of the cask
3 motion -- I'm sorry, the pad motion?
4 DR. LUK: Yes, those are the two
5 horizontal that form the axis that we use in the
6 model.
7 MR. TURK: If we look on this chart for
8 point A, I see a peak that occurs at approximately 10
9 seconds in time, and that is the red peak.
10 DR. LUK: Yes.
11 MR. TURK: At 0.06 inches, correct?
12 DR. LUK: Correct.
13 MR. TURK: What does that peak represent?
14 DR. LUK: The peak represents the maximum
15 relative displacement of the bottom of the pad at
16 point A with respect to its corresponding point on the
17 top of the cement-treated soil.
18 MR. TURK: Then the same would be true if
19 we look at other charts presented in this exhibit.
20 For instance, if you go to the next page, this is for
21 point F, correct?
22 DR. LUK: Yes.
23 MR. TURK: And that is the same point F
24 represented on page 1 of this exhibit?
25 DR. LUK: Yes.

1 MR. TURK: Shown there? And here you saw
2 a peak relative displacement of the pad in the U1
3 direction at approximately, say, 12.5 or 13 seconds in
4 time, of about .09 inches?
5 DR. LUK: A little more than .09, but
6 relatively speaking, yes.
7 MR. TURK: Okay. Then the same on the
8 next page it was point G. For that point, there was
9 something a bit in excess of .1 inch relative
10 displacement of the pad vis-a-vis the CTS. That looks
11 to be about a .17 perhaps at 10 seconds?
12 DR. LUK: Yes.
13 MR. TURK: Again, that is .17 inches of
14 relative displacement?
15 DR. LUK: Yes.
16 MR. TURK: I'm sorry, not .17, but .117?
17 DR. LUK: Yes, yes.
18 MR. TURK: It is just shy of the .12 inch
19 mark?
20 DR. LUK: Yes.
21 MR. TURK: Okay.
22 JUDGE LAM: Dr. Luk, are these points
23 plotted at the bottom of the pad on top of the soil?
24 DR. LUK: Yes, all these are the two
25 nodes. One is at the bottom of the pad; the other one

1 is a corresponding matching mode at the top of the
2 cement-treated soil.
3 CHAIRMAN FARRAR: Is there any reason why
4 the scale of, for example, these first two graphs is
5 slightly different?
6 DR. LUK: Your Honor, we are trying to
7 maximize the space that is permitted on the page. So,
8 yes, you are correct. If we have more time, we can
9 refine the plot so that they are using the same scale.
10 But the significance we tried to demonstrate there,
11 yes, there is relative displacements between the
12 bottom of the pad and the top of the cement-treated
13 soil, but the amount of relative displacements that we
14 are talking about are very small.
15 CHAIRMAN FARRAR: Okay. So when I look at
16 10 seconds, for example, the red line, 10 seconds, it
17 moves a sixteenth of an inch at point A, and even
18 though it looks like less, it is almost the same
19 sixteenth of an inch at point F?
20 DR. LUK: I'm sorry, Your Honor, it's six
21 hundredths of an inch.
22 CHAIRMAN FARRAR: Right, six -- isn't that
23 a sixteenth of an inch?
24 DR. LUK: Well, it's .06 inch.
25 CHAIRMAN FARRAR: Yes, okay. But then

1 when I look at the blue line at five seconds --

2 MR. TURK: On what chart, Your Honor?

3 CHAIRMAN FARRAR: Both. Point A has moved

4 only four hundredths and point F at about the same

5 time has moved twice as far. Does that mean -- this

6 lateral movement, right? What I would call lateral

7 movement?

8 DR. LUK: Yes, sir.

9 CHAIRMAN FARRAR: Sliding?

10 DR. LUK: Yes.

11 CHAIRMAN FARRAR: Does that mean it is

12 rotating around point A? Or partly rotating around

13 point A? I'm trying to figure out what this means in

14 the physical world.

15 DR. LUK: Yes, but it also means that

16 those displacements that you are talking about do not

17 occur at the same time. In the static sense, yes. In

18 a dynamic sense, you will also have a certain amount

19 of very slight rotations, but since they didn't occur

20 at the same time, it is hard to figure out in which

21 way they are going to go for the rotations.

22 CHAIRMAN FARRAR: Okay, I guess I'm --

23 DR. LUK: You're correct in a sense.

24 CHAIRMAN FARRAR: I am having trouble

25 figuring how point A moves laterally and point F

1 doesn't move laterally at the same time.

2 DR. LUK: Well, in a way it does, but not

3 necessarily in -- if you are looking at the scale of

4 the problem, the magnitude of relative displacement

5 that we are talking about is probably well within the

6 numerical accuracy of the model. In that sense, we

7 acknowledge there is a difference, but this probably

8 has no significance in going through the calculations

9 for structural response.

10 MR. TURK: I may be the only one who needs

11 this clarification --

12 (Pause.)

13 CHAIRMAN FARRAR: Dr. Luk, part of the

14 answer to the problem I am having, that these are

15 elastic things, and therefore, A or F can get

16 separated from each other. Okay?

17 DR. LUK: Yes, I think it is the amplitude

18 of the differences we are talking about is so small,

19 they are well within the elastic behavior.

20 CHAIRMAN FARRAR: Okay.

21 JUDGE LAM: And in your model, all bodies

22 are elastic bodies, right?

23 DR. LUK: Yes, sir.

24 CHAIRMAN FARRAR: Okay, go ahead, Mr.

25 Turk.

1 MR. TURK: I may be the only one who
2 thinks that this clarification is even necessary, but
3 when you stated that the magnitude of the relative
4 displacement is well within the numerical accuracy of
5 the model, were you suggesting that there may be no
6 relative displacement at all? It is just something
7 that appears in the results of the model, but in fact
8 it may not even exist in reality?
9 DR. LUK: The answer is as follows: We
10 are engineers. We try to solve an engineering
11 problem. From the engineering perspective, looking at
12 analysis results, the magnitude of the displacement
13 that we are discussing now is so small. That is the
14 reason why I said it is well within the numerical
15 accuracy of the finite elements model.
16 MR. TURK: Okay. Also, this is relative
17 displacement, correct?
18 DR. LUK: Yes, sir.
19 MR. TURK: It may not be the pad sliding.
20 It may be just a difference in motion between the CTS
21 and the pad rather than actual sliding of the pad,
22 correct?
23 DR. LUK: Yes.
24 MR. TURK: In effect, did you find --
25 CHAIRMAN FARRAR: Wait, wait a minute. I

1 don't get that.

2 MR. TURK: Okay.

3 CHAIRMAN FARRAR: I understand that it is

4 relative, but the question Mr. Turk just posed

5 conjured up in my mind that one slid and the other

6 slid more or less.

7 DR. LUK: Correct. Yes, it is one

8 movement in reference to the other.

9 CHAIRMAN FARRAR: Right. So it is not that

10 neither one slid? It's that they slid differentially?

11 DR. LUK: Correct, sir.

12 CHAIRMAN FARRAR: Or stretched

13 differentially?

14 DR. LUK: Correct.

15 MR. TURK: Or vibrated differentially?

16 DR. LUK: Yes. I think, yes, a vibration

17 is actually a better term because of the dynamic

18 nature of the event.

19 JUDGE LAM: Now, Dr. Luk, with 200,000

20 nodes, what convergence criteria do you use? Aren't

21 these numbers probably within your convergence

22 criteria?

23 DR. LUK: Yes, sir. We went through a

24 hierarchy of convergence evaluations. Some of them

25 have to do with the different size of the elements.

1 We have all different models that include the cask,
2 the pad, the cement-treated soil, as well as the
3 foundations. In particular, at the end of phase we
4 have the contact elements. So all those elements were
5 evaluated in relation to a convergence of the
6 numerical results.
7 JUDGE LAM: Because the pad is about 60-
8 feet long, if you see relative displacement of 0.06
9 inch, it means it is not moving?
10 DR. LUK: For engineers, yes, it simply
11 indicated that there is not much movement at all,
12 relative movement. I'm sorry.
13 MR. TURK: And I believe in your testimony
14 previously, back in May, as I recall, you indicated
15 the amount of displacement of the pad was so
16 negligible as to be, you could consider it to be
17 nonexistent?
18 DR. LUK: Yes.
19 MR. TURK: Would that be a correct
20 statement on your part?
21 DR. LUK: Yes.
22 MR. TURK: Okay.
23 CHAIRMAN FARRAR: If this is all within,
24 if I can paraphrase it, the margin of error of your
25 model, then you're offering this, Mr. Turk, just to

1 show that the motion is negligible?

2 MR. TURK: Yes, I think maybe the next

3 question will simply wrap it up.

4 CHAIRMAN FARRAR: But this is relative

5 displacement. What does this show about absolute

6 displacement? In other words, could they both be

7 moving?

8 DR. LUK: Yes. I think we actually

9 witnessed a lot of things that, for example, on tables

10 performed by the Japanese, for example, you can

11 actually witness significant absolute movements of the

12 structures, but here we are talking about relative

13 displacement between two bodies.

14 They can, in a higher dynamic seismic

15 event, a structure can displace quite some distance.

16 We are talking about inches and maybe tenths of

17 inches.

18 MR. TURK: I think I can help, if I may,

19 Your Honor?

20 CHAIRMAN FARRAR: Okay.

21 MR. TURK: The concern raised by Dr.

22 Bartlett was that your model did not achieve, or did

23 not attempt to be consistent with the PFS design

24 intent that there not be sliding of the pad relative

25 to the CTS. Based on what you see here in Staff

1 Exhibit YY, what is your belief as to whether you
2 achieved in your modeling that design intent of no
3 sliding of the pad relative to the CTS?
4 DR. LUK: Our models actually assume that
5 the bottom of the pad can slide with reference to the
6 top of the cement-treated soil, and our analysis
7 results strongly indicated that there is not much
8 relative movement at all. Now in that sense, it
9 confirmed the design intent.
10 MR. TURK: One other question. I'm sorry.
11 DR. LUK: And if you don't mind me
12 elaborate a little bit, it's a recommended practice
13 that if people started with a finite elements model by
14 not allowing any relative movement at this interface,
15 that's between the bottom of the pad and the top of
16 the cement-treated soil, you will never be able to
17 confirm or validate how good is the model, because it
18 does not allow it to move to begin with. So our
19 approach is that we allowed it to move, and later find
20 out that the relative displacements are actually
21 small, so in that sense, we're not only going to
22 incorporate all the necessary intent for the design,
23 but we'll also be able to validate the accuracy of the
24 modeling approach.
25 JUDGE LAM: Now this allowance for

1 movement is dictated by assigning a value of the
2 friction coefficient. Is that true?
3 DR. LUK: Yes, it's by prescribing a
4 numerical value for the coefficient of friction, but
5 also we use the contact elements at the interface.
6 JUDGE LAM: Uh-huh. You mean the contact
7 stiffness.
8 DR. LUK: Yes.
9 MR. TURK: Let me -- I have a couple of
10 questions I'd like to ask as follow-up, but I don't
11 want to interrupt any of the Board's questions.
12 CHAIRMAN FARRAR: Yeah, give us a moment
13 here. Go ahead, Mr. Turk.
14 MR. TURK: Judge Farrar asked you a
15 question about absolute displacement. If, in fact,
16 you're not finding any relative displacement between
17 the pad and the CTS, does that mean that the entire
18 system, i.e., the soils, the CTS, and the pad are
19 moving together? Or would that be a possible
20 explanation of what absolute motion is occurring?
21 DR. LUK: Yes, they do move together in an
22 absolute sense.
23 MR. TURK: But your purpose with this
24 exhibit is not to show the absolute movement, but
25 rather whether there is sliding of the pad on the CTS.

1 DR. LUK: Yes.

2 MR. TURK: Incidentally, I should have
3 asked you this earlier. Do the graphs shown in this
4 exhibit correlate with any of the models presented in
5 your report of March 31? Which case is this that
6 you're presenting?

7 DR. LUK: Oh, I have to make reference to
8 the report on the March 31st, 2002. If you go to
9 Table 10 on page 32, the results that we plot are for
10 the case -- the fourth case in this table.

11 MR. TURK: And that's the one that is for
12 the lower bound soil condition with Mu1=.80 U2=1.0?

13 DR. LUK: Yes, sir.

14 MR. TURK: In fact, you did the same sort
15 of -- you could have presented results for other
16 cases, as well as for this one. Correct?

17 DR. LUK: Yes.

18 MR. TURK: And is the reason -- can you
19 explain the reason why this is the one that you're
20 presenting?

21 DR. LUK: This is our last analysis case.
22 Because of the huge size requirement for each of the
23 output for the analysis case, as a standard practice
24 we got through Q/A procedures with input file, but we
25 do not include the output file. But we also have to

1 have it -- to keep the output file for the last
2 analysis case that we did. And this actually
3 represents the last cases that we performed.
4 MR. TURK: So.just as a matter of the need
5 to discard previous material as you go through all
6 these different runs, this is simply the one that was
7 the last one that you ran, and this is the one that
8 was on hand and available to you to bring today.
9 Correct?
10 DR. LUK: Yes.
11 MR. TURK: And again, it's your view that
12 this would bound the 2000 year case for relative
13 displacement of the pad on the CTS?
14 DR. LUK: Yes.
15 MR. TURK: Your Honor, I would ask that
16 Staff Exhibit YY be admitted into evidence.
17 CHAIRMAN FARRAR: Any objection?
18 MR. GAUKLER: No objection, Your Honor.
19 MS. CHANCELLOR: May I ask a few
20 questions?
21 CHAIRMAN FARRAR: Certainly.
22 MS. CHANCELLOR: Dr. Luk, when did you
23 create -- just to clarify, when did you create the
24 data to develop the plot?
25 DR. LUK: We actually have the output file

1 for this analysis case, because this represents the
2 last analysis case that we did.
3 CHAIRMAN FARRAR: But she asked you when.
4 DR. LUK: Oh. We did that two or three
5 weeks before the end of March, this year.
6 MS. CHANCELLOR: And all the plots in
7 Staff Exhibit YY are based on that one case. Correct?
8 DR. LUK: Yes.
9 MS. CHANCELLOR: Okay. And when did you
10 create the plots?
11 DR. LUK: We created plots last Saturday,
12 because I have to ask my colleague to show up to
13 basically finish this for me.
14 MS. CHANCELLOR: And when you say "we",
15 did you create the plots, or your colleagues?
16 DR. LUK: We actually have a team, so I
17 asked my colleague to put that together.
18 MS. CHANCELLOR: And who was that?
19 DR. LUK: Dr. Benjamin Spencer.
20 MS. CHANCELLOR: And do you still have the
21 data that you created these plots from?
22 DR. LUK: Yes.
23 MS. CHANCELLOR: And these were finaled on
24 Saturday, the plots?
25 DR. LUK: Yes.

1 MR. TURK: I'm sorry. I didn't hear the
2 question. These were what?
3 MS. CHANCELLOR: Finaled.
4 MR. TURK: Finalized.
5 DR. LUK: Yes.
6 MS. CHANCELLOR: We have no objection,
7 Your Honor. No objection.
8 CHAIRMAN FARRAR: All right. Then Staff
9 YY will be admitted.
10 (Staff Exhibit YY admitted in evidence.)
11 MR. TURK: Okay. Incidentally, when you
12 say this was put together on Saturday, did you put it
13 together for purposes of introducing in response to
14 Dr. Bartlett's rebuttal testimony?
15 DR. LUK: Yes, I was thinking that it's
16 better to give these members of the public hearing, in
17 particular, the judges the quantitative assessment of
18 the issues on hand. So it's much better if we can
19 product results for this particular issue.
20 MR. TURK: May I ask also, the five charts
21 that are attached as part of this exhibit appear to be
22 for the interior nodal points in the pad; that is,
23 Points A, F, G, H, I. That's correct?
24 DR. LUK: Yes.
25 MR. TURK: You also performed the same

1 plotting for Points B, C, E and D that are on the
2 perimeter of the pad?
3 DR. LUK: Yes.
4 MR. TURK: Did you find any significant
5 difference between the amount of relative displacement
6 at those outer perimeter nodes, vis a vis the inner
7 perimeter, or the ones that are shown here?
8 DR. LUK: There is slight differences at
9 those four outer points, but the differences are not
10 very significant, so they are well within the same
11 order of magnitude.
12 MR. TURK: Would those differences be on
13 the order of perhaps .01 to .02 inches difference
14 between the amount of relative displacement for those
15 points, vis a vis the relative displacement shown
16 here?
17 DR. LUK: Yes.
18 MR. TURK: And again, if we are looking at
19 a 2000 year case, would we approximately cut that
20 difference in half so that you would have no more than
21 roughly a .1 to a .005 delta between the amount of
22 relative displacement for those outer nodal points?
23 DR. LUK: .05.
24 MR. TURK: I'm sorry. .005.
25 DR. LUK: No, .05, because the order of

1 magnitude is .1.

2 MR. TURK: Right. I'm talking about the

3 delta, but you're saying there would be --

4 DR. LUK: Oh, yeah.

5 MR. TURK: -- there would be essentially

6 a maximum displacement of about a point --

7 DR. LUK: .05.

8 MR. TURK: Now I'm lost.

9 DR. LUK: .05.

10 CHAIRMAN FARRAR: No, these are only .0.

11 MR. TURK: The maximum displacement shown

12 here is roughly a .1 inch?

13 DR. LUK: Yes.

14 MR. TURK: Maximum relative displacement.

15 DR. LUK: yes.

16 MR. TURK: For the nodes at the outer

17 perimeter for this 10,000 year case, I understand what

18 you're saying to be that you might get like a --

19 instead of a .1, you would get a what, a .12?

20 DR. LUK: Yeah, .12 or -- yes.

21 MR. TURK: Okay. And for the 2000 year

22 case, would your answer that you gave us before be

23 essentially correct, that you would expect that value

24 of approximately .12 inch to be halved down to about

25 a .06 inch relative displacement for the 2000 year

1 case?

2 DR. LUK: Yes.

3 MR. TURK: All right. Your Honors, I may

4 come back to this with respect to specific statements

5 made by Dr. Bartlett, but I'd like to move on now to

6 a different concept, and that is the Young's modulus

7 that was used in the modeling.

8 CHAIRMAN FARRAR: All right.

9 MR. TURK: Dr. Luk, you heard Dr.

10 Bartlett's criticism of your use of a Young's modulus

11 of 270,000 PSI for the cement-treated soil. Correct?

12 DR. LUK: Yes.

13 MR. TURK: Why did you use the 270,000 PSI

14 Young's modulus?

15 DR. LUK: Well, first of all, in

16 communicating with Dr. Mahendra Shaw, that he is the

17 one who give this information to us. We go through

18 discussions, and it is our mutual understanding to use

19 a higher value for the Young's modulus. We only going

20 to come up with a more conservative case related to

21 the dynamic response of the cask.

22 In that, what we simply mean is that in

23 doing analysis, it's very important for us to keep

24 track where the energy goes. In that regard, by using

25 a higher Young's modulus, simply indicating that most

1 of the energy that's associated with the ground
2 excitations would go more to the movement of the pad
3 and the cask. In that sense, we are generating an
4 upper bond solutions for the dynamic behavior of the
5 cask. That is the focus of our investigation.
6 MR. TURK: And in doing that, was it your
7 intent to be sure that you can see the greatest amount
8 of possible displacement or rotation of the cask, your
9 analytical results?
10 DR. LUK: Yes.
11 MR. TURK: You indicated that in your
12 discussions with Dr. Shaw, you mutually understood
13 that you should use that higher Young's modulus value.
14 Do you agree that that's an appropriate use of the
15 higher Young's modulus in this modeling?
16 DR. LUK: Yes, but we also went through
17 sensitivity analysis. What we find out is that the
18 selection of the value for Young's modulus is a
19 secondary nature, at best, in effecting the analysis
20 results. What that simply means is that the analysis
21 results are not sensitive to the input values for the
22 Young's modulus.
23 JUDGE LAM: Did you, in fact, look at
24 75,000 PSI?
25 DR. LUK: We did not look at the 75,000

1 PSI for the Young's modulus, but we did go through
2 some changes and find out it's not significant.
3 MR. TURK: Let me ask you the same
4 question with respect to Dr. Bartlett's criticism of
5 your modeling two feet of soil cement, I'm sorry,
6 cement-treated soil beneath the pads. Why did you use
7 the two foot figure for the CTS?
8 DR. LUK: It was my understanding when I
9 communicated with Dr. Mahendra Shaw there may be a
10 variation in the thickness of cement-treated soil
11 underneath the pad, but we decided to use the higher
12 value for the thickness of the cement-treated soil for
13 the reasons I'll just mention. If we have a
14 relatively stiffer cement-treated soil, more of the
15 energy that's associated with the ground excitations
16 will go the pad and the cask, so in that sense, more
17 conservative results will be generated in evaluating
18 the dynamic behavior of the cask.
19 MR. TURK: And do you believe it was an
20 appropriate modeling technique for you to use this
21 input of two foot for the CTS?
22 DR. LUK: Yes.
23 MR. TURK: And as I understood your use of
24 the term, that you would obtain more conservative
25 results because you used the two foot CTS, and I

1 believe we had the same sort of explanation of why you
2 used 270,000 PSI Young's modulus. Does that indicate
3 that, in your view, if you had used the lower values
4 of 75,000 PSI Young's modulus, and perhaps a one foot
5 or a one and a half foot cement-treated soil, that you
6 would have seen less cask displacement, and less cask
7 rotation above the pads than your modeling actually
8 showed?
9 DR. LUK: We did not use the thickness of
10 the cement-treated soil as a sensitivity parameter.
11 But it's also our understanding in the past three
12 years, through various considerations of various input
13 parameter for the soil profile data, the relative or
14 the selection of any thickness for a given layer in
15 the soil foundation, the analysis results are not very
16 sensitive to that. But a very critical point in our
17 modeling approach is that we do analysis of soil
18 foundations by self, and I explicitly request the
19 support from Mr. Po Lam. He's trained in that area -
20 okay - so we have detailed evaluation of the soil
21 foundation response behavior, subject to the given
22 seismic excitations. And in that sense, the
23 significance of the thickness for any given horizontal
24 layer in the soil foundation model, they do not offer
25 a highly sensitive results in relationship to the

1 accuracy of the modeling. But the important issue is
2 that every step of the way, going from the given input
3 that we got from NRC related to the soil profile data,
4 and go through the decompilation process, go through
5 the one 1-D Shake Model, go through the 2-D Dynaflow
6 model, and eventually put into the 3-dimensional
7 coupled
8 models using the Abaqus Code. A basic requirement is
9 that we use the same set of informations throughout
10 the process.
11 MR. TURK: Maybe I didn't express my
12 previous question quite clearly enough. Do you
13 believe that the amount of cask displacement and cask
14 rotation shown in your report would equal or bound the
15 amount of cask displacement and rotation that you
16 would find if you had used the lower values that Dr.
17 Bartlett discussed for Young's modulus and cement-
18 treated soil depth?
19 DR. LUK: As I indicated, not significant
20 difference in that respect would show up, if we use a
21 value for Young's modulus equals to -- what's the
22 value?
23 MR. TURK: 75,000?
24 DR. LUK: Yeah, 75,000, as well as when we
25 used a one foot thickness for the cement-treated soil.

1 MR. TURK: Dr. Lam asked you before about
2 the use of an elastic value for the different
3 components in the model; that is, for the soils, for
4 the CTS, for the pad. In fact, you used elastic
5 values for those components. Am I expressing that
6 correctly? Did you model them as elastic?
7 DR. LUK: Yes. All the substructures in
8 the 3-dimensional coupled models are elastic in
9 nature.
10 MR. TURK: Is it typical among experts who
11 do finite element analysis modeling to use elastic
12 properties for those types of structures in the model?
13 DR. LUK: Yes. I make reference to all
14 the seismic analysis in various disciplines. For
15 example, in nuclear components, in nuclear industry,
16 in the highway bridges, in the dam calculations, when
17 people model soil foundations they basically model
18 them as elastic bodies. But it's also a good analysis
19 practice, once we make the assumptions and develop the
20 model, it is our duty also to go through close
21 analysis evaluations to make sure that we have
22 analysis results to validate the assumptions that we
23 made. And in this case, the soil behavior is in
24 elastic domain.
25 MR. TURK: Is?

1 DR. LUK: Is in elastic domain. That
2 means, they behave elastically.
3 MR. TURK: It is in the elastic domain.
4 DR. LUK: Yes.
5 MR. TURK: And you state that based on the
6 results of your modeling?
7 DR. LUK: Yes.
8 MR. TURK: When you say that the soil
9 behavior -- what you're saying is you found the soil
10 behavior to be elastic. Correct?
11 DR. LUK: Yes.
12 MR. TURK: How do you correlate that with
13 Dr. Bartlett's concern that there may be some
14 deficiency in your model with respect to the post
15 yield behavior of soils?
16 DR. LUK: Yes. When people look at such
17 complicated problem, and when we first developed the
18 model, obviously, we tried to use as elaborate as
19 possible a modeling the behavior. We did try to
20 consider the plastic behavior of soil, but as it
21 turned out, they are not very significant, and that's
22 why after a few months of evaluations, it is the
23 decisions from our team, saying that the modeling by
24 using elastic body to simulate the soil foundation is
25 adequate.

1 It is also in regard to how much
2 appletical solution that we can get. And I think the
3 people, of course, can argue within the technical
4 arena there's no such behavior as elastic, but we are
5 very much concerned with eventually it is one of our
6 tasks to develop appletical analysis model that can be
7 used by people in the industry. By modeling the
8 plastic behavior in the model, we are going to talk
9 about -- we're going to change the order of magnitude
10 of the size of the model, maybe by a factor of at
11 least two to three. But the essence, more at stake
12 here is that how will the behavior of the soil
13 foundations affect the problems on hand, which is the
14 seismic stability of cask. We find out even if people
15 try to use plastic model to simulate the soil
16 foundations, there will not be -- the difference will
17 not be significant to warrant the application of a
18 plastic model for the soil foundations. As a matter
19 of fact, that has been the current analysis practice.
20 MR. TURK: When you say that's "the
21 current analysis practice", you're talking about among
22 experts in the field of finite element analysis
23 modeling?
24 DR. LUK: I'm talking about for people who
25 applied finite elements methodology in performing

1 seismic analysis, because of the excessive amount of
2 calculations that's involved, mainly because the
3 Delta-T that we use in the model is very, very small.
4 For our case it's 4X10-5th decade. What that simply
5 means is that for a seismic event, it's 30 divided by
6 4X10 to the minus 5th cycles. That is the number of
7 cycles that's involved in the analysis, so in result
8 it's actually 7.5 times 10 to the 5th power. That's
9 the number of calculations.
10 MR. TURK: The number 30 that you used,
11 that's the 30 second --
12 DR. LUK: That is the 30 second for the
13 seismic event.
14 MR. TURK: Okay. By the way, I may have
15 this -- I apologize to the applicant. I may have
16 misled Mr. Trudeau yesterday when I suggested a 40
17 second earthquake. In fact, it's a 30 earthquake
18 that's postulated for the PFS 2000 year design
19 earthquake. Correct?
20 DR. LUK: Yes.
21 MR. TURK: Did you adjust the -- did you
22 perform any adjustments to the elastic - maybe I'm
23 going to say this wrong. Did you use a shear modulus
24 in your model for the soils?
25 DR. LUK: Yes, as indicated in Tables 2 to

1 7.

2 MR. TURK: Did you make any adjustments to

3 your modeling of the elastic behavior to account for

4 shear strain loads, or to account for the stress-

5 strain behavior of the soil?

6 DR. LUK: Can you rephrase the question?

7 MR. TURK: Well, I may need to come back

8 to this. I'm not sure I understand it properly myself

9 yet.

10 CHAIRMAN FARRAR: Mr. Turk, in terms of

11 planning a break, how much more do you have?

12 MR. TURK: I have one more general area,

13 but then I'd like to go back into Dr. Bartlett's

14 specific testimony. So perhaps, if for a minute I

15 could ask that last general area, that might be a good

16 time to break.

17 CHAIRMAN FARRAR: Okay.

18 MR. TURK: The last criticism that I

19 understood Dr. Bartlett had raised had to do with your

20 consideration of the Pecoima Dam earthquake record for

21 the 1971 San Fernando earthquake. Do you recall his

22 testimony in that regard?

23 DR. LUK: Yes, sir.

24 MR. TURK: And as I recall, he indicated

25 that he felt the use of that earthquake record was

1 inappropriate because it understated the peak ground
2 accelerations that would exist at the PFS site for the
3 2000 year earthquake. Do you recall that line of
4 testimony?
5 DR. LUK: Yes.
6 MR. TURK: Why did you use the San
7 Fernando Pecoima Dam earthquake record?
8 DR. LUK: First of all, let me respond.
9 I think the response from the other witness is not
10 correct, and the reason for that is that - okay - we
11 use artificial time history of seismic gyrations as
12 input to our model. But we also ask the following
13 questions, what will be the seismic behavior of the
14 cask if this model is subjected to a realistic
15 earthquake event? So we have a lot of choices, and
16 our final selection, the final selection was based on
17 the selections by the NRC Staff, in particular, Dr.
18 Mahendra Shaw, that we take San Fernando, the Pecoima
19 Dam earthquake records. And the reason for that is
20 that - okay - while it's probably -- we want to use
21 well-established database for seismic event, not very
22 far away. And the purpose of all of this effort is
23 nothing more than trying to go through a sensitivity
24 evaluations on whether the seismic behavior of the
25 cask would change much if our models are subjected to

1 a different seismic content.

2 But also, in particular, the reason why I

3 said, you know, the response from the other witness is

4 probably not technically accurate is that when people

5 look at seismic excitations, it's not just the

6 amplitude that's important. In a lot of cases, the

7 frequency contained actually dominates instead of the

8 amplitude, so in that regard it's very important for

9 us to use actual earthquake records, that has a

10 different content in terms of amplitude, as well as

11 frequency.

12 MR. TURK: When you mentioned the other

13 witness, you're referring to Dr. Bartlett?

14 DR. LUK: Yes, sir.

15 MR. TURK: Dr. Bartlett also indicated he

16 thought there were any number of earthquakes that

17 could have been used for this purpose in your model.

18 Do you agree with that statement?

19 DR. LUK: Yes.

20 MR. TURK: Now when you say any number,

21 are you saying they could be on the order of hundreds

22 of earthquakes for which adequate data exists for your

23 use in your modeling?

24 DR. LUK: Well, I think for the people

25 practicing in the field of doing the seismic analysis,

1 we're talking maybe 10 to 20.

2 MR. TURK: A total of 10 or 20

3 earthquakes?

4 DR. LUK: Yes.

5 MR. TURK: And are most of those located

6 outside, or most of those were located outside the

7 United States?

8 DR. LUK: Yes.

9 MR. TURK: Did you consider it to be

10 important to use an earthquake record for an

11 earthquake that occurred within the United States?

12 DR. LUK: Well, we --

13 MR. TURK: Or close to the United States

14 borders?

15 DR. LUK: Yes.

16 MR. TURK: And how many such earthquakes

17 exist among these 10 or 20 that you considered to be

18 adequately supported by data for your use?

19 DR. LUK: Well, for example, we can use

20 Tibet. We can use the Taiwan earthquake. AS a matter

21 of fact, those are the two seismic excitations record

22 that we used for the San Fernando cask analysis.

23 MR. TURK: San Onofree?

24 DR. LUK: Oh, yes. San Onofree. I'm

25 sorry. We can also use the one in Mexico City. We

1 can also use the one in Japan of the Kobe earthquake,
2 or we can use the El Central record that is outside of
3 San Diego area.
4 MR. TURK: You believe that your use of
5 the Pecoima Dam record 1971 San Fernando Valley
6 earthquake was an appropriate choice of earthquake for
7 your purposes in your model, running your model?
8 DR. LUK: For the purpose of performing
9 sensitivity evaluations for our focus on the seismic
10 stability of the cask, we feel that's adequate.
11 MR. TURK: Incidentally, you indicated
12 that the final choice was made by Dr. Shaw in this
13 regard. Do you agree with the choice?
14 DR. LUK: Yes.
15 MR. TURK: Did you consult with Mr. Po Lam
16 about this matter?
17 DR. LUK: Oh, yes. As a matter of fact,
18 among Dr. Shaw, Mr. Po Lam and myself, we have
19 substantial communications before we finally decide on
20 the choice.
21 MR. TURK: And is it fair to say that all
22 three of you agree that that was appropriate choice
23 for an actual real earthquake to model as you ran your
24 PFS site-specific analysis?
25 DR. LUK: Yes.

1 MR. TURK: Your Honor, that concludes my
2 general questions. During the break, if you wish to
3 have one, I'll go and see if I can fine-tune any
4 further questions I may have.
5 CHAIRMAN FARRAR: Okay. Let me just ask,
6 before we do that, one question. What happened to the
7 -- or why don't you use, or have you used it under a
8 different name, the San Francisco World Series
9 earthquake of 10 years ago? Was that not big enough?
10 DR. LUK: I think it's big enough, but
11 it's the -- whether the record for the seismic event
12 is substantially collected and documented. Mainly
13 because, you know --
14 CHAIRMAN FARRAR: Why wouldn't it be out
15 there?
16 DR. LUK: Well, because you need to
17 basically have instrumentations installed at various
18 locations before the seismic event for you to collect
19 the seismic records. And there is not enough sensor
20 locations for the San Francisco area.
21 CHAIRMAN FARRAR: Okay.
22 DR. LUK: Yes, so the hindsight is that,
23 you know, it would be perfect if you put a lot of
24 things there, but --
25 CHAIRMAN FARRAR: I assume if they had a

1 lot of things there it --

2 DR. LUK: No.

3 CHAIRMAN FARRAR: No. Okay. All right.

4 Then let's take a break. Mr. Gaukler, how long are

5 you going to need when it's turn?

6 MR. GAUKLER: I would say 15 minutes.

7 CHAIRMAN FARRAR: Ms. Chancellor?

8 MS. CHANCELLOR: It's hard to guess. I'm

9 guessing one to two hours. Sorry.

10 MR. TURK: And to be sure that I've

11 expressed myself clearly, I do expect to conduct some

12 more examination of Dr. Luk after the break, probably

13 on the order of 45 minutes.

14 JUDGE LAM: So we're not getting done by

15 5 today, huh?

16 CHAIRMAN FARRAR: Well, maybe we'll put

17 some time limits in. We'll talk about that during the

18 break. It's 5 of, let's be back at 10 after.

19 MS. CHANCELLOR: One thing, Your Honor, we

20 may need to bring Dr. Bartlett back, depending on Dr.

21 Luk's testimony.

22 CHAIRMAN FARRAR: That's another

23 surrebuttal. Okay.

24 (Off the record 3:44 p.m.)

25 CHAIRMAN FARRAR: Mr. Turk, how much more

1 time do you need?

2 MR. TURK: Your Honor, I hate to cut

3 myself off. I'm estimating 45 minutes. It's probably

4 going to be an hour.

5 CHAIRMAN FARRAR: Mr. Gaukler, how much

6 time do you need?

7 MR. GAUKLER: Ten.

8 CHAIRMAN FARRAR: Good. Mr. Turk, you can

9 have 15 minutes. Mr. Gaukler, you can have 10

10 minutes. We're finishing Dr. Luk today. Ask the

11 questions that are most important. Give direct, short

12 answers.

13 DR. LUK: Yes.

14 CHAIRMAN FARRAR: If you want a minute to

15 think about which questions you want to ask, go ahead.

16 And the situation we have here is this is the State's

17 first chance to cross examine Dr. Luk after having had

18 some time to think over the deposition and his report,

19 all of which were -- arrived very late, so -- and Dr.

20 Luk is leaving the country?

21 MR. TURK: Actually, no. He's going back

22 to Alberquerque tomorrow, and his plans have changed.

23 He's now planning a trip to Hawaii next week.

24 CHAIRMAN FARRAR: Well, we're finishing

25 him tonight, and we're not going extremely late, so

1 you've got 15 minutes.

2 MR. TURK: All right. I'll try to focus

3 on key points, Your Honor, as I hope I've been doing

4 until now.

5 One question I'd like to start with, Dr.

6 Luk, is a question by Dr. Lam. He asked you about

7 convergence. Now as I understood that question, Judge

8 Lam was asking about whether you attempted to run a

9 convergence for the different time changes, the Delta-

10 T, if I'm not mistaken.

11 JUDGE LAM: That's right.

12 MR. TURK: Could you address that a little

13 bit more?

14 DR. LUK: Yes. We choose to use the

15 explicit version of Abaqus Code so the selection of

16 the Delta-T is actually by the code itself. In that

17 regard, the convergence criteria was part of the

18 formulation of the theory. And in that sense, the

19 convergence or the selection of the Delta-T has been

20 taken care of by the code.

21 MR. TURK: You indicated that you don't

22 believe it's appropriate for someone to use the Mohr-

23 Coulomb theory of failure as Dr. Bartlett has done in

24 attempting to describe the interface between different

25 bodies in your model. Would you explain why you

1 believe that's not appropriate?

2 DR. LUK: First of all, Mohr-Coulomb

3 theory of soil is prescribed to describe the variable

4 behavior of soil, so it's part of the material

5 properties for soil. And at the interface, we only

6 consider the physical phenomena of frictional

7 resistance. In that regard, the frictional resistance

8 is more sensitive to the surface conditions, and if

9 you don't mind me make one example.

10 We can look at concrete to concrete

11 sliding one top of the other. For dry cases, was the

12 worst cases. You can have for the dry case, the upper

13 bound of a coefficient of friction as high as .8, but

14 then for the wet conditions, can be as low as .2, but

15 we are using the same material. So the choice of the

16 selection of coefficient of friction is more sensitive

17 to the surface condition than the material, so in that

18 regard, the coefficient of friction is not a material

19 property.

20 MR. TURK: And on that same line, is it

21 correct that you are not attempting to model material

22 properties when you constructed your model of the

23 interface?

24 DR. LUK: Yes, sir.

25 MR. TURK: And in your view, that would

1 have been an incorrect way to proceed, modeling of
2 material properties?
3 DR. LUK: Yes, but also in --
4 MR. TURK: I'm sorry. For the interface.
5 DR. LUK: Yes, sir. But it's also in
6 particular Mohr-Coulomb theory of failure prescribed
7 to describe the failure mechanism of soil material,
8 and that is not part of the modeling effort.
9 MR. TURK: In your model, did you use a
10 strain-dependent elastic modulus?
11 DR. LUK: Yes.
12 MR. TURK: And could you explain what that
13 means?
14 DR. LUK: Yes, for the 2000 years return
15 seismic event, the shear modulus as a material
16 property for soil is independent of the state of shear
17 strength, but because of the high level of strain,
18 then large deformation theory would be used for the
19 10,000 years seismic event, so the shear modulus is a
20 function of shear strength in the soil foundations.
21 MR. TURK: In my questioning of Dr.
22 Bartlett today, I came back to a point he had made in
23 his rebuttal testimony on June 7, with respect to his
24 belief that perhaps an inappropriate modeling of soils
25 done by you might be the explanation for the 6G spike

1 that is shown, I believe, in Figure 17 of your report.
2 Do you believe that's a proper interpretation of the
3 reason why that spike might appear?
4 DR. LUK: First of all, I think you make
5 reference to Figure 17?
6 MR. TURK: Yes.
7 DR. LUK: Okay. Those --
8 MR. TURK: I'm sorry. May I have just a
9 moment?
10 DR. LUK: Yes.
11 MR. TURK: If you would, take a look at
12 Figure 20b in your report.
13 DR. LUK: Yes.
14 MS. CHANCELLOR: Your Honor, is this
15 within the scope of surrebuttal?
16 CHAIRMAN FARRAR: It doesn't matter. He's
17 only got 15 minutes.
18 MS. CHANCELLOR: Okay.
19 CHAIRMAN FARRAR: He can use it however he
20 wants.
21 MR. TURK: There was a concern expressed
22 by Dr. Ostadan and Bartlett both, about the high
23 acceleration figure that would be shown in Figure 20b.
24 And I thought that what Dr. Bartlett was saying was
25 that perhaps the way you modeled soils might account

1 for the spike. Could you explain what would account
2 for any spikes in acceleration in Figures 17 through
3 22 with response to accelerations?
4 DR. LUK: Yes, There is in existence high
5 values for accelerations at nodes that we try to plot
6 in all these figures. What it basically means is that
7 yes, there's existence of high G Values, but the
8 questions that we ask is that how significant are
9 these high acceleration values at a single node, in
10 contributing to the structural response of the cask?
11 And the answer is not significant, and the reasons
12 are, first of all, the duration during which this high
13 G, high acceleration values occur is very, very short.
14 And in terms of calculating the impulse, the impulse
15 is, by definition, is the force times T. If the
16 Delta-T is significantly small, so even with a
17 relatively high acceleration result, the product of
18 the two is small.
19 And more importantly, for the selection of
20 the node that we pick is actually at the boundary.
21 Now what I simply mean is that that is correct, if
22 inside a continuum there will not be significant
23 difference of variations between nodes and nodes.
24 Okay? But if we're talking about an element right at
25 the boundary, in particular for this case, there is a

1 node at the boundary, so averaging process should be
2 followed. And I need to quantify the term "averaging
3 process".
4 In our finite elements methodology that we
5 used, we used eight node cubic elements. What I
6 simply mean is that every element has eight nodes, so
7 in order to calculate the structural response it's
8 more important trying to find out the results at all
9 those eight nodes, and go through an averaging, so
10 that will be actually the response for the element
11 instead of a single node.
12 MR. TURK: So the points you've made are
13 it's a single node, it's a small time increment, and
14 it's a boundary node.
15 DR. LUK: Yes.
16 MR. TURK: And, in fact, if you're saying
17 that it's a boundary node, would that mean that if you
18 see a 6G or some G acceleration in those figures, that
19 that would not be what you would expect to see. And
20 on the same plane, for a node located within the
21 structure that is not on the boundary of the
22 structure.
23 DR. LUK: Within that element, so it's a
24 very small distance away. All those high values for
25 acceleration results will not show up. It shows up

simply because of the presence of the boundary. And for people who do this class of dynamic analysis, it is not a surprise. Those high values does show up, but the final question to ask is that, whether all those things would contribute anything in the structural response, because I have witnessed in the proceedings of this testimony, they -- that means there's two witness from the State that say they have seen, because we have provided in our analysis report, high acceleration values, but they don't understand why it did not show up in the structural response. And the answer is what I just offered.

MR. TURK: And also, you had mentioned previously that these also include high frequencies that have not been damped because you only use a single term of damping.

DR. LUK: Yes, but I think for this case I explicitly tried to say even in the low frequency domain response, those two reasons do apply. One, is the Delta-T, the time duration involved for this high acceleration values, when at times there's very, very small Delta-T, it does not significantly contribute to the structural response. And second, those high acceleration results only occurred at the node at the boundary of the element. So if you go through the

1 averaging process, significant reductions will occur.
2 And that actually are the main reasons why the overall
3 structural response of the cask are not very high.
4 MR. TURK: When you use Mu2 equals to 1.0
5 for the interface between either the CTS and the pad,
6 or the CTS and the soil, does that maximize the amount
7 of sliding of one structure upon the other, as Dr.
8 Bartlett seems to believe, or is the converse true?
9 DR. LUK: The converse is true.
10 MR. TURK: So that using a Mu of 1.0 will
11 give you less sliding than using a lower value for
12 that Mu at the interface. Correct?
13 DR. LUK: Yes.
14 MR. TURK: Is it correct that you did not
15 attempt to model sliding on a granular material?
16 DR. LUK: The granular material is never
17 included in our model.
18 MR. TURK: Let me be a little more clear.
19 We're talking about the interface.
20 DR. LUK: Yes, there's no material at the
21 interface.
22 MR. TURK: But you were not attempting to
23 model sliding on a granular material, such as sand or
24 gravel.
25 DR. LUK: Well, if the material doesn't

1 exist, we in no way try to simulate granular material.
2 MR. TURK: I think that's probably a poor
3 use of my limited time remaining, so I'll move on. I
4 thank you.
5 Dr. Luk, is it fair to say that you are
6 aware of the site-specific properties at the PFS site
7 with respect to soils and foundations?
8 DR. LUK: Yes. We are given three sets of
9 site-specific soil profile data.
10 MR. TURK: So if there was a suggestion by
11 the State that you're not aware of what the site-
12 specific properties are, that would be an incorrect
13 statement by the State.
14 DR. LUK: Correct.
15 MR. TURK: There has been a suggestion
16 that you simply took the values for the site-specific
17 properties at face value. Do you believe that's a
18 correct representation of what you did?
19 DR. LUK: No. As a matter of fact, among
20 Dr. Mahendra Shaw, Mr. Po Lam and myself, we went
21 through a substantial amount of communications to make
22 sure we used the proper inputs to our model, because
23 we are fully aware the integrity of the analysis
24 results are based on the accuracy of the input
25 parameters.

1 CHAIRMAN FARRAR: That's it, Mr. Turk.
2 Mr. Gaukler, I want to make sure you understand the
3 basis of our ruling, because it has nothing to do with
4 anything you've done here today. Dr. Luk is here.
5 The Staff had two and a quarter hours today to cross
6 examine Dr. Bartlett. They've had an hour and a half,
7 with Dr. Luk's help, they've had an hour and a half to
8 do direct exam of Dr. Luk, and the huge issue here is
9 the late filing, the late emergence of the Luk report,
10 which again was no one's fault, but the State is going
11 to get their opportunity to cross examine him, while
12 we indulge in the fiction here that what you're about
13 to do is cross examination. He is -- Dr. Luk's
14 position, in fact, supports your application, even
15 though it's a somewhat different theory, so that's why
16 we're cutting you back, not because of anything -- any
17 misdeeds on --
18 MR. GAUKLER: I believe 10 minutes will be
19 adequate for me, Your Honor.
20 CHAIRMAN FARRAR: Before you start, Dr.
21 Luk, you mentioned some time ago Shake Tables. You
22 learned something about the Japanese Shake Table, I
23 think.
24 DR. LUK: yes.
25 CHAIRMAN FARRAR: Do I recall correctly

1 that in your earlier testimony here, you indicated
2 that you had at one point asked Dr. Singh and Dr.
3 Solar for a cask because you wanted to set up a shake
4 table test?
5 DR. LUK: Yes, sir.
6 CHAIRMAN FARRAR: And what happened?
7 DR. LUK: When we first --
8 CHAIRMAN FARRAR: Short answer.
9 DR. LUK: Yes.
10 CHAIRMAN FARRAR: Did you get it, you
11 didn't get it?
12 DR. LUK: We did not get it.
13 CHAIRMAN FARRAR: Okay.
14 DR. LUK: Can I --
15 CHAIRMAN FARRAR: No.
16 MR. TURK: It may be useful to your
17 understanding of shake table testing.
18 CHAIRMAN FARRAR: I'll ask the questions.
19 Are you of the view now that a shake table test would
20 be useful in confirming your analysis?
21 DR. LUK: Yes, sir.
22 CHAIRMAN FARRAR: Tell me about it.
23 DR. LUK: Last week we had a meeting at
24 NRC for the team, that include our project manager at
25 NRC, and also there is a recent development at the

1 University of San Diego -- the University of
2 California at San Diego, that a few months ago they
3 started a proposal to the National Science Foundation.
4 I was asked by them to write a letter of
5 recommendation as one of the five tasks they propose
6 to do on the new shake table facilities at the UCSD.
7 And two weeks ago, they were granted a huge funding
8 from the National Science Foundation to exactly do
9 that. And in that regard, I have communicated with
10 our NRC project manager, and he agreed that he would
11 put that test proposal on the table in the next
12 funding cycle for the NRC. So in that regard, we're
13 actually going to have the true state-of-the-art test,
14 shake table test facilities.
15 CHAIRMAN FARRAR: But if I understand your
16 answer, you're looking at that as a generic
17 possibility, or generic approach to take to seismic
18 design. You're not recommending it for this
19 particular project, or are you?
20 DR. LUK: I think it's -- if you don't
21 mind me modify a little bit your question, is that
22 once we identify the facility, we are going to use a
23 full-sized cask. Then it will be up to the Staff at
24 NRC to decide what should be the design of the cask,
25 and also, what should be the input seismic to put on

1 the shake table.

2 CHAIRMAN FARRAR: Okay. When you talk

3 about seismic input, the seismic input for that test

4 can't be any better than the seismic input you put in

5 the model. Right? I mean, the same data that you

6 used in your model, the earthquake time histories is

7 the same thing you would use in the shake table.

8 DR. LUK: But except I think the NRC Staff

9 will be the group that will decide which groups of

10 time history of seismic excitations should be used.

11 CHAIRMAN FARRAR: Right, but you -- but

12 there are only so many of them. I mean, you can't

13 create new ones. I mean, you're stuck with what you

14 have.

15 DR. LUK: Yes, but then there is

16 differences for every site-specific time history of

17 seismic excitations.

18 CHAIRMAN FARRAR: But then when you do the

19 shake table test, don't you have a problem in making

20 sure that this -- even if you get the full-sized cask,

21 in making sure the surface of the table reflects the

22 reality of a particular site?

23 DR. LUK: We try to put in as much as

24 technically feasible. That is actually the reason why

25 these new test facilities will be outdoor, because

1 three years ago we had the problems, we cannot
2 actually bring a full cask into an indoor facility.
3 JUDGE LAM: Is this facility built
4 already, or is it pending?
5 DR. LUK: Two weeks ago they got the
6 funding. I was told maybe by spring next year, they
7 may have the facility ready to go, because they have
8 a significant portion of the facilities already. All
9 they have to do is to move the current one from indoor
10 to outdoor, and then have some enhancements in the
11 facilities.
12 CHAIRMAN FARRAR: Is there anyone in your
13 group who thinks shake table tests are not useful at
14 all?
15 DR. LUK: Can you repeat the question,
16 sir?
17 CHAIRMAN FARRAR: Is there anyone in your
18 group who thinks that shake table tests are not useful
19 at all in these circumstances?
20 DR. LUK: Nobody within the group saying
21 that it's not useful. I think, in particular, because
22 of some of the uncertainties that's reviewed from the
23 analysis, it has given people more incentive, trying
24 to push for testing.
25 CHAIRMAN FARRAR: Thank you, Dr. Luk, go

1 ahead Mr. Gaukler. And I think we said 15 minutes.

2 CROSS EXAMINATION

3 BY MR. GAUKLER:

4 Q Dr. Luk, you were saying that the

5 coefficient of friction is not a property of the

6 materials, but it is a function of the interface,

7 correct?

8 A Yes.

9 Q Now, how did you include the properties,

10 soil properties, in your soil model, in your modeling

11 of the PFS site?

12 A Okay. We are given a site specific soil

13 profile data, and in there we develop layers,

14 horizontal layers for the soil foundations. And all

15 those specific properties are incorporated into the

16 model.

17 Q So the properties of the soil would be

18 incorporated into the finite elements that comprise

19 the soil layers at the site, correct?

20 A Yes.

21 Q And therefore, right at the interface, you

22 would have a layer of finite elements for the soil,

23 for example, correct?

24 A Yes. And that is within the soil

25 foundation.

1 Q Within the soil foundation. And those
2 finite elements would include the site specific soil
3 properties for the PFS site, correct?
4 A Yes.
5 Q And the site specific soil properties
6 would, in effect, model, appropriately model the soil
7 at the site, based upon the data that you had received
8 for the site, correct?
9 A Correct.
10 Q And, further, the model, the Abuqus model
11 that you used would, in effect, model whatever effect
12 cohesion may have, too, with respect to the soil,
13 correct?
14 A Yes.
15 Q So you include cohesion in your model in
16 that respect?
17 A That is well within the model of the
18 Abaqus code.
19 Q And by putting the soil properties in your
20 finite elements the model, effectively, computes the
21 cohesion value for the soil properties you put in,
22 correct?
23 A Yes. That is actually the reason why we
24 pick Abaqus code, because there is substantial
25 documentations on the theory of what has been

1 incorporated into the code.

2 Q And so, therefore, when Dr. Bartlett

3 claims you modeled the soils as a granular material,

4 that is exactly incorrect, right?

5 A Well, it is more important than that. I

6 was, you know, trying to answer Mr. Turk. There is no

7 material at interface.

8 Q Right, but --

9 A -- to suggest that I use something to

10 simulate granular material at the interface is not

11 appropriate.

12 Q And, moreover, you did not model the soils

13 at the PFS site as a granular type soil, such as sand?

14 A No, we used the site specific soil profile

15 data that was given to us.

16 Q So you modeled the soils underneath the

17 cement treated soil as the Bonneville clay soils that

18 exist at the site, correct?

19 A Yes.

20 Q Now, you were saying that by allowing your

21 model to slide you, in effect, the outdated PFS

22 design's attempt, by that I take it, if I can

23 summarize what I understood your testimony to mean, is

24 that you put in the properties of the soil that PFS as

25 designed, and Abaqus modeled how that would affect the

1 pad, and the cement treated soil, and in your model
2 you allowed, at the interfaces, you allowed sliding to
3 occur.
4 And, in fact, if sliding did occur you
5 would see it, correct?
6 A Yes.
7 Q And, in fact, displacement shocks you
8 found showed that, in effect, no sliding occurred at
9 this displacement?
10 A Very small.
11 Q Very small?
12 A Yes.
13 Q And this refers to Staff's exhibit YY. Do
14 you have that in front of you?
15 A Yes.
16 Q The Staff exhibit YY, I have a couple of
17 questions for clarification. Which is, first of all,
18 this is the time history of the relative displacements
19 of these nodes for the entire 30 second time history
20 for the earthquake, correct?
21 A Yes.
22 Q And when you were talking about increments
23 you were talking about Abaqus uses an increment of 5
24 times 10 to minus 4, or something like that?
25 A Four times 10 to minus 5th power.

1 Q Four times 10 to the minus 5th. So
2 basically what you are saying is that each one of
3 these dots will show sliding, you broke dow -- this
4 graph here is really broken down into each point, you
5 did a point for every 4 times 10 to the minus 5
6 seconds?
7 A Well, I think we also would include the
8 process, because there are too many sets of results.
9 So we may skip, you know, every hundreds of them.
10 Q Okay.
11 A Because even then the number of data is
12 still huge. But the essence of the matter is that the
13 durations during which high results occur, are still
14 very, very small.
15 Q And, in fact, this shows -- so this, in
16 effect, shows the maximum total displacement you
17 received at any particular point in time?
18 A Yes.
19 Q It measured the increments you identified,
20 correct?
21 A Yes.
22 Q And that is where you say you got the .1
23 inch, I believe you said?
24 A Yes.
25 Q Now, if I also understood your testimony

1 to Mr. Turk, you incorporated different soil models
2 for the 2,000 year and a 10,000 year earthquake,
3 because of the difference in the amplitude for the
4 earthquake? Is that correct, or did I misunderstand
5 that?
6 A I think different soil profile data has
7 been used in terms of the upper bound, lower bound,
8 and the best estimate.
9 Q Okay. Now, going back to Staff exhibit
10 YY, what I also understood you to say is that these
11 displacements that you see are consistent with the
12 elastic properties of the materials.
13 In other words, you could just see these
14 displacements, just based upon looking purely at the
15 elastic properties of the materials, without sliding,
16 correct?
17 A Well, what we are saying is that the
18 behavior of the soil is well within the elastic
19 region. So in that sense this plot represent the
20 elastic behavior.
21 Q Now, based on the model that you have done
22 for the PFS site, and the model you've done for San
23 Onofree, using the same model you've done for the
24 Hatch plant, you've modeled different sites under
25 different conditions, correct?

1 A Yes.

2 Q And you see a range of results with your

3 model, correct?

4 A Yes.

5 Q And you've used the same model, the same

6 basic model in all three of those instances, correct?

7 MR. TURK: I would object without

8 understanding what we mean by the same basic model.

9 THE WITNESS: I can answer the question.

10 I think, we used the basic model for all the three

11 sites, but for the Private Fuel Storage site, because

12 of the presence of the cement treated soil, or soil

13 cemented layers, we actually have to substantiate the

14 model, or modify the model to incorporate that

15 feature.

16 BY MR. GAUKLER:

17 Q So you used the same general modeling

18 methodology, you expanded the model for the PFS site

19 to include cement treated soil and soil cement?

20 A Yes, sir.

21 Q And you, obviously, had different input

22 for the different sites, correct?

23 A Yes.

24 Q And you were able to predict a range of

25 results?

1 A Correct.

2 Q That seemed, to you, to correspond to

3 reality, correct?

4 A To the best of our knowledge and to the

5 best that we can use for the state of the art for

6 methodology, yes.

7 Q And you did that to this date, correct?

8 A Yes.

9 CHAIRMAN FARRAR: Good job. Thank you,

10 Mr. Gaukler.

11 JUDGE LAM: Let me clarify, on the record,

12 by asking Dr. Luk one quick question.

13 In response to my question Dr. Bartlett

14 had indicated he believed the issue of cohesion of the

15 soil is an inherent deficiency in your model. I

16 believe, by listening to your answers to Mr. Turk and

17 Mr. Gaukler, your response would be -- would you

18 please fill in the blank?

19 THE WITNESS: Our response is that, I

20 assume you are addressing the specific issue at the

21 interface.

22 At the interface we only prescribed the

23 coefficient of fiction based on the Coulomb's Law of

24 friction. So in that sense there is no material,

25 there is no cohesions associated with the soil

1 material.

2 JUDGE LAM: So Dr. Bartlett's assertion of

3 the issue of cohesion as an inherent deficiency of the

4 model, in your opinion, is not correct?

5 THE WITNESS: Yes, sir.

6 JUDGE LAM: Okay, thank you, that is all

7 I needed.

8 CHAIRMAN FARRAR: Ms. Nakahara, it is now

9 10 minutes to 5. As I said, it is important, given

10 the background here, that you have a full opportunity

11 to cross examine Dr. Luk.

12 Let me make a couple of suggestions.

13 Number one, pretend you are us and just ask whatever

14 you want, you don't need background, you don't need

15 preface, just ask the question.

16 Number two, if the witness gives you more

17 of an answer that you need, feel free to thank him for

18 his answer, and we will cut him off. No disrespect to

19 you, Dr. Luk, but we've got to focus on what they

20 think is important.

21 And, third, if it gets to a point where

22 you think it is efficient to do so, I believe both the

23 Staff -- I know the Staff, I think also the Applicant

24 has used the provision of the regulations which -- the

25 State did?

1 MS. NAKAHARA: Yes, State did.

2 CHAIRMAN FARRAR: Okay. If you want to do

3 that again, where the technical witness does the

4 questioning, you can do that.

5 So it is now 10 to 5, go for it.

6 MS. NAKAHARA: Thank you, Your Honor. I

7 don't think I can be as efficient as Mr. Gaukler, but

8 I will try.

9 CROSS EXAMINATION

10 BY MS. NAKAHARA:

11 Q Mr. Gaukler asked you questions relating

12 to whether you had correlated soil properties into

13 your finite element model, as finite elements.

14 What do you consider soil properties?

15 A The soil properties that we input in our

16 finite elements model included in tables 2 to 7 in our

17 analysis report.

18 Q So you consider the soil cement adjacent

19 to the pad to be soil properties?

20 A Yes.

21 Q And you consider the soil cement, or the

22 cement treated soil underneath the pad to be soil

23 properties?

24 MR. TURK: I'm sorry, soil properties of

25 what?

1 CHAIRMAN FARRAR: Never mind, just keep
2 asking your questions. Mr. Turk, we are going to get
3 through this.
4 MR. TURK: I understand, Your Honor, but
5 the --
6 CHAIRMAN FARRAR: I will worry about that,
7 all right?
8 BY MS. NAKAHARA:
9 Q And also in response to a question by Mr.
10 Gaukler you stated that the cohesion properties of
11 soil are accounted for in Abaqus, correct?
12 A Yes.
13 Q How are they accounted for?
14 A I think if you really need to go through
15 the theories, once you prescribe the material
16 properties in terms of the Young's modulus ratio
17 density, damping ratios --
18 MR. TURK: Your Honor, let me just ask.
19 I won't interrupt, but if the witness hears a question
20 that he believes is unclear, or needs to clarify, I
21 would ask him to do that, so that I don't have to
22 object to the form of the question.
23 CHAIRMAN FARRAR: He will do that, but
24 that was the first question she asked, you had an
25 objection, we are not going to have it.

1 MR. TURK: I don't intend to obstruct, it
2 was the form of the question that bothered me, I'm
3 very happy to have the witness examined, as long as
4 the question is not confusing.
5 CHAIRMAN FARRAR: Dr. Luk, if you have any
6 trouble with any question you don't understand, feel
7 free to say that you don't understand it. Or as you
8 did with my question, you modify it to what you
9 thought I meant, what I would have asked if I was
10 smart enough to ask the right question.
11 That is fine, you can help us along here.
12 But don't talk too fast.
13 THE WITNESS: Okay. So the answer is that
14 we are given a set of soil profile data. And all
15 those data was properly input into the model, would
16 represent the soil behavior.
17 So whether it is a cohesion, or adhesion
18 effect, they are all incorporated. Now, if you really
19 want, I think, I need to bring the theory manual for
20 Abaqus to demonstrate how they are incorporated.
21 But I know, because I studied those theory
22 manuals, they are incorporated.
23 BY MS. NAKAHARA:
24 Q I hate to do this, but could you repeat
25 the properties that Abaqus considers? You stated

1 Young's modulus, and --

2 A Yes, I'm sorry. All those properties are

3 actually included in tables 2 through 7. That

4 includes Young's modulus, shear modulus --

5 Q Okay, that is fine, thank you. And are

6 you aware that PFS' design for the cement treated soil

7 underneath the storage pad must, or will create a

8 cohesive bond with the clay layer beneath the cement

9 treated soil?

10 A In the process of communicating with Dr.

11 Mahendra Shaw I was aware of that. But I think our

12 job is to try to incorporate the soil profile data

13 specific to the Private Storage site, as the way that

14 they were given.

15 And it was actually all included in tables

16 2 to 7. Yes, because if you look at table 2, for

17 example, we have 8 inches of gravel, two foot and four

18 inches of what we call the soil cement adjacent to

19 pad, and followed by two foot of soil cement

20 underneath the pad.

21 So all those materials that was given to

22 us, and we have input into the model.

23 Q I understand that you view Coulomb's Law

24 of Friction to model the interface between the cement

25 treated soil underneath the pad, and the clay layer

1 supporting that cement treated soil. That is correct,
2 right?
3 You used Coulomb's law to model the
4 interface?
5 A We used Coulomb's law to represent a
6 physical phenomenon associated with a sliding
7 resistance, based on Coulomb's Law of Friction.
8 Q But if the actual design that PFS is
9 proposing is a cohesive bond, why did you use
10 Coulomb's Law of Friction?
11 A As I stated previously, if -- okay, we try
12 to follow a good modeling method. What I simply mean
13 is that if we allowed relative displacement occurred
14 at interface, but as it turned out, the amount of
15 relative displacement is so significantly small, we
16 more or less confirmed the design content.
17 In that way we actually be able to give
18 credibility and confirmation of the analysis method.
19 So by having to assume a bounded case to begin with,
20 there is no way for us to find out how good is the
21 model.
22 Q But in this case you were modeling a site
23 specific facility, which is the PFS site, correct?
24 A Yes.
25 Q Earlier in response to a question from Mr.

1 Turk, you mentioned that finite elements used
2 coefficient of friction to model the interfaces
3 between structures, correct? Or something to that
4 effect?
5 A Can you repeat the question?
6 Q In response to Mr. Turk, is it true that
7 you stated that finite analysts typically use a
8 coefficient of friction to model the interface between
9 structures? I may have misunderstood that.
10 A Can you clarify your question?
11 Q You used Coulomb's Law of Friction,
12 correct, to model the interface between the layers,
13 the various layers at the PFS site?
14 A Yes.
15 Q Is that typical of what other finite
16 analysts do?
17 A Oh, yes, definitely.
18 Q And when you say it is typical of what
19 other finite analysts do, is it typical to model two
20 different soil layers using Coulomb's Law of Friction?
21 A I think people use Coulomb's Law
22 ofFriction to simulate a sliding friction behavior for
23 various kinds of materials. That includes steel,
24 concrete, various kinds of soils and, even for that
25 matter, wood.

1 Q And what about for cohesive materials?

2 A Again, that coefficient of friction, based

3 on Coulomb's Law of Friction does not deal, in

4 particular, with a material.

5 The cohesion is a material property.

6 That is why, I think, there is a disconnect, in a

7 sense. At the interface there is no material, so you

8 do not prescribe or assign any material properties at

9 the interface.

10 You only prescribe the amount of sliding

11 resistance according to Coulomb's Law of Friction.

12 Q Are you aware that PFS will create a

13 physical bond in between the cement treated soil layer

14 and the clay layer?

15 A I was informed that that is the design

16 intent. That is the reason why we are trying to use

17 a very high coefficient of friction. In that case

18 what we use, for the coefficient of friction, equals

19 to 1.0.

20 And we are trying to see how good is our

21 model, as indicated that analysis results demonstrate

22 that there is no significant relative displacements at

23 this interface.

24 Q So isn't it true there is a material in

25 between the two layers?

1 A No, there is not a material in the
2 interface. A way in doing modeling, trying to
3 prescribe a physical phenomena, when one body slides
4 with respect to the other.
5 Q So you are speaking in the modeling sense?
6 A Yes.
7 Q Okay.
8 A Yes.
9 Q Have you ever modeled the interface
10 between a cement treated soil layer, and a clay layer,
11 previously?
12 A Yes. In my previous life with the weapons
13 calculations, soil is one of the predominant material.
14 Q Was cement treated soil?
15 A Not really for cement treated soil, but it
16 is a soil, and all kinds of soils.
17 Q Have you seen other analysts, finite
18 element analysts, who have modeled the interface
19 between cement treated soil and a clay layer?
20 A We have looked into the interactions of
21 various kinds of soil, in the highly dynamic event of
22 the weapons calculations, yes. But not in particular
23 with the cement treated soil, because it is not one of
24 the natural geological material that we do our
25 calculations.

1 Q In your weapons experience modeling the
2 interface between two soil layers, did you use
3 Coulomb's Law of Friction?
4 A Yes.
5 Q What type of soil materials were they?
6 A Like I said, I think we go all the way to
7 the gravel, and the other extreme is granite. So it
8 is from very soft soil to very hard rock. So there is
9 a wide spectrum of geological material.
10 Q Is gravel considered a soft soil?
11 A In our calculation for the weapons effect
12 it is actually very significant. But I don't think
13 that that has much relevance here.
14 Q I believe in response to Mr. Turk you
15 stated that it is the practice of Sandia labs to allow
16 the structures to move when you model the response, is
17 that correct?
18 A No, I said this is a good engineering
19 practice, or good analysis practice. That we make
20 some assumptions and, later, when we finish the
21 analysis, we go through close analysis evaluations,
22 try to make sure that our assumptions are correct.
23 And if we do find out the assumptions are
24 not correct, then we have to change the model. So we
25 are trying to end up with a set of results, is that

1 the assumptions that we made in a modeling are
2 consistent with the output, so that we are not
3 conflicting ourselves.
4 Q And did you allow the structures to move
5 relative to each other in the analysis you conducted
6 at the Hatch Plant?
7 A Yes.
8 Q And you also allowed the structures to
9 move relative to each other at San Onofree?
10 A Yes.
11 Q Isn't it true at the Hatch Plant you did
12 not create an interface between the bottom of the
13 storage pad and the soil?
14 A That is correct. We have two layers of
15 interface for the Hatch Plant. The one at the top is
16 between the bottom of the cask, and the top of the
17 concrete pad. And the second one is between the
18 bottom of the pad and the top of the soil foundations.
19 Q And what was the coefficient of friction
20 you used at the Hatch plant, between the bottom of the
21 pad, and the top of the soil layer?
22 A I do not have the precise value in front
23 of me, because the work was done quite some time ago,
24 it is actually out of sight, out of mind.
25 Q I have the report.

1 CHAIRMAN FARRAR: What was that you gave
2 the witness?
3 MS. NAKAHARA: I will read the title. It
4 is Dr. Luk's analysis, cask stability analysis at the
5 Hatch Plant.
6 CHAIRMAN FARRAR: Okay.
7 MR. TURK: It would help if Ms. Nakahara
8 has a page reference she wants to give him, or does
9 she want the witness to find it?
10 MS. NAKAHARA: No, I didn't think he
11 modeled the interface, that is why I'm asking.
12 THE WITNESS: Your Honor, I need to have
13 some time, and try to withhold the response, but I
14 promise I will give answer later.
15 MS. NAKAHARA: That is fine.
16 CHAIRMAN FARRAR: Ms. Nakahara, where are
17 you going with this? In other words, when he finds
18 the answer what does that do for us?
19 MS. NAKAHARA: Well, I thought that he
20 hadn't modeled the interface between the pad and the
21 soil, and so this would be the first instance in which
22 he attempted to do that.
23 CHAIRMAN FARRAR: Okay.
24 MS. NAKAHARA: And just a verification, so
25 later is fine.

1 CHAIRMAN FARRAR: Okay. Then let's hold
2 that for now. And can you do other questions without
3 the answer to that?
4 MS. NAKAHARA: Yes.
5 CHAIRMAN FARRAR: Okay, Dr. Luk, we will
6 hold that for later.
7 THE WITNESS: Yes.
8 CHAIRMAN FARRAR: Or if there is a break
9 in the action, for some other reason, you can check it
10 out. Thank you.
11 BY MS. NAKAHARA:
12 Q Dr. Luk, you may want to refer to that
13 document again.
14 Isn't it true that the Hatch site is not
15 a soil site, considered a soil site?
16 A I think casks is always put on the soil,
17 but it is the different category of soil, because the
18 earth surface, by nature, is soil.
19 Q Isn't it true that the Hatch site is not
20 comparable to the PFS site, the clay layer soil, the
21 clay layer at the PFS site?
22 A Yes, I think that those two sites have
23 quite different site specific soil profile data.
24 Q And would you expect the interface between
25 the Hatch soil and the pad to be different than the

1 clay layer at the PFS site, and -- strike that, let me
2 try and ask it again.
3 Would you expect the interface to behave
4 differently at the Hatch site between the pad and the
5 soil, and versus the PFS site between the cement
6 treated soil layer, and the clay layer?
7 MR. TURK: If you understand the question.
8 THE WITNESS: Can you repeat the question?
9 BY MS. NAKAHARA:
10 Q Would you expect the interface between the
11 bottom of the pad and the soil at the Hatch site to
12 behave differently than the bottom of the cement
13 treated soil layer and the clay layer at PFS?
14 A Yes, if you don't mind me substantiating
15 a little bit, and you can stop me any time you want.
16 It is that this is actually our conclusions after we
17 go through three site specific analysis.
18 It is that in which way we can simplify
19 the model. And, one, we did go through a detailed
20 evaluation try to find out specifically the interface
21 between the bottom of the pad and the top of the soil
22 foundations.
23 Is that adequate to assign a coefficient
24 of friction equals to 1.0. And then we go through a
25 systematic evaluations, and is the recommendation from

1 our team, that is adequate.

2 And in that regard we actually cut down

3 the time of the model by a factor of 2. So in that

4 regard, yes. If we had this hindsight of the

5 interface between the bottom of the pad and the top of

6 the soil foundations, it is not significant.

7 Because this is more or less a physical

8 phenomena. When you have a concentrated mass of casks

9 on top of a pad, sitting on a relatively soft soil

10 foundations, the physics will dictate the layer of

11 soil foundation in a close vicinity of the bottom of

12 the pad would go together with the pad.

13 And that is what the analysis results

14 indicated to us, would more or less duplicate a

15 physical phenomena.

16 Q And isn't it true at the San Onofree site

17 is not the -- strike that.

18 Are the casks at the San Onofree site

19 sitting on a storage pad?

20 A Can you repeat the question?

21 Q Are the casks at the San Onofree site

22 sitting on a storage pad, a concrete storage pad?

23 A Yes.

24 Q And the supporting, the foundation soil

25 for the storage pad at the San Onofree site that is

1 not clay, correct?

2 A We input the site specific soil profile

3 data as given to us. I am, in particular, are not

4 interested in what soil category those soil layers

5 are. But it is more important to me that we input the

6 proper soil properties data as given to us for the

7 specific site.

8 Q How does that affect the interface in

9 between the soil foundation and the upper layer?

10 A In a way if they are given as -- if we

11 input those soil properties data on the first layer of

12 our soil foundation, the way that we are supposed to

13 do it properly, we plan that we have properly

14 incorporated the top soil layer in our model.

15 Q And who is responsible for developing the

16 interface model between the different layers, the

17 cement treated soil layer, and the clay layer?

18 A I am responsible for all the models about

19 the soil foundation.

20 Q And did you have input from other

21 individuals on your team?

22 A Yes. As a matter of fact, you know, I

23 developed the model, and subjected the review for our

24 team members. But it was also later reviewed by the

25 NRC Staff, and was further reviewed by our review

1 panel.

2 Q When you say your team members who,

3 specifically, on your team?

4 A The team members are actually described at

5 the top of the front page of the analysis report,

6 which include a few members from NRC, that include me,

7 Dr. Smith, Mr. Obi, and also contractors from Anatech

8 Corporation, Mr. Bob Dameron, and also from Earth

9 Mechanics, Mr. Po Lam.

10 Q And isn't it true that you are not an

11 expert in soil mechanics?

12 A Yes, I'm not an expert in soil mechanics.

13 But that is also the reason why we hire experts in

14 soil mechanics as part of the team.

15 Q And who did you hire?

16 A We hired, as a contractor, Mr. Po Lam.

17 Q And isn't it true Mr. Po Lam is a

18 seismologist?

19 A He is trained in geotech area, but he

20 spends a lot of time in doing seismic analyses. So I

21 think, technically, he is a geotech engineer.

22 Q He has extensive experience in modeling

23 the soil mechanics of soils?

24 A Yes.

25 Q And Mr. Lam evaluated your interface

1 model, correct?

2 A No. As I said, Mr. Lam's role in this

3 task is that he is responsible for the modeling of the

4 soil foundations. My role is to do everything about

5 soil, including interface.

6 Q Mr. Lam evaluated the interface model

7 between the cement treated soil and the clay layer,

8 correct?

9 A The interface conditions, in particular

10 with the contact elements, I developed but it was

11 reviewed by Dr. Smith and Mr. Dameron. Those two

12 people are trained in the structural engineering area.

13 Q Didn't you previously testify that you

14 considered the cement treated soil layer a soil

15 material, and not a structure?

16 MR. TURK: I would object, I don't think

17 the question was posed that way. The question was, do

18 you consider the soil cement to be a soil. And at

19 that point I was objecting, and I was ruled out of

20 order because of confusion in the question.

21 CHAIRMAN FARRAR: Can you give an answer

22 to the right question?

23 THE WITNESS: Yes. I think in the sense

24 of the finite elements modeling, methodology, they are

25 treated equally, because we have a specific material

1 type for those elements, and in that regard for the
2 material.
3 So whether it is a structure, or it is a
4 soil, once we define the material type with a given
5 set of material properties, those are the special
6 characteristics for that layer of elements in a model.
7 BY MS. NAKAHARA:
8 Q Who, in your team, had expertise in the
9 behavior of soil cement?
10 A Like I said, the cement treated soil in
11 this Private Fuel Storage site is particular of its
12 own nature. We don't really have explicit experience
13 in this area. But in formulating the model in the
14 arena of finite elements methodology, it does not
15 matter what is that specific category of geological
16 material.
17 But what is more important that if we are
18 given the proper material properties, that if we also
19 go through the proper input of that into the layer to
20 simulate the cemented soil, cement treated soil, we
21 consider we have properly included that sublayer in
22 the model.
23 JUDGE LAM: Now, wait, Dr. Luk. It does
24 matter in the sense that you do not have two different
25 types of material in the given element. I mean, given

1 that is taken care of, then you don't really care,
2 whether structural or soil. Is that correct?
3 THE WITNESS: Yes, because that was
4 actually indicated in tables 2 to 7. We use a
5 different set of material for the two foot four inches
6 adjacent to the concrete pad. And also to the two
7 foot of cement treated soil underneath the pad.
8 They have two different sets of material
9 properties.
10 JUDGE LAM: Yes.
11 BY MS. NAKAHARA:
12 Q In your opinion would the soil cement
13 adjacent to the pad control -- strike that.
14 In your opinion the two soil materials, is
15 the interface in between those materials not
16 controlled by the interface? Strike that.
17 Just for this one question can I ask Dr.
18 Bartlett to ask the question? F
19 DR. BARTLETT: For modeling two soil
20 materials that are in contact with each other, is the
21 interface conditions that govern between those two
22 soil materials, also function of the material
23 properties?
24 MR. TURK: Object to using the word also.
25 That is contrary to what the testimony has been until

1 now.

2 CHAIRMAN FARRAR: Overruled, go ahead.

3 THE WITNESS: Again, like I said, in

4 between two materials there is interface. There is no

5 material at the interface. We prescribed Coulomb's

6 Law of Friction for assigning numerical value for the

7 coefficient of friction. And that is all we did.

8 DR. BARTLETT: For two soil materials?

9 THE WITNESS: For any two material, for

10 any two structures, because they are all represented

11 by finite elements.

12 DR. BARTLETT: For two cohesive materials

13 to derive their strength primarily from cohesion, is

14 the interface condition between these two materials

15 also a function of the material properties?

16 THE WITNESS: In a way you are correct,

17 because when you have highly cohesive material the

18 numerical value of coefficient of friction at the

19 interface of these two highly cohesive soil, it would

20 be reflected by a higher coefficient of friction.

21 In that sense it is inclusive, but has no

22 model to correlate the coefficient of friction to the

23 cohesion for the two soil types.

24 BY MS. NAKAHARA:

25 Q Couldn't you use Mohr-Coulomb theory?

1 A Can you repeat the question?

2 Q Couldn't you use, as a mathematical model

3 Mohr-Coulomb theory?

4 A Oh, yes. There is tons of literature for

5 the coefficient of frictions based on the Coulomb's

6 Law of Friction, mainly because that is a highly

7 sought after set of informations, because the

8 coefficient of friction at any interface between two

9 bodies are very sensitive to the service conditions.

10 JUDGE LAM: I thought Ms. Nakahara asked

11 you, could the Mohr-Coulomb theory of failure be used

12 to estimate the coefficient of friction.

13 THE WITNESS: Oh, I'm sorry.

14 JUDGE LAM: Is that what you meant, Ms.

15 Nakahara?

16 MS. NAKAHARA: Not the coefficient of

17 friction, but the interface conditions. It was my

18 understanding, Dr. Luk --

19 MR. TURK: Can we just have the question

20 reread and see if Dr. Luk properly understood it? It

21 appears, Judge Lam, the question seemed to use the

22 words the Mohr-Coulomb theory, rather than the

23 coefficient of friction that is Coulomb's Law of

24 Friction.

25 MS. NAKAHARA: That is what I said. Mohr-

1 Couloumb --

2 MR. TURK: I think Dr. Lam misunderstood,

3 is that correct?

4 JUDGE LAM: Yes.

5 MR. TURK: So perhaps we could get a

6 correct answer to a question that he properly

7 understands.

8 THE WITNESS: Yes, the correct answer is

9 that if the question is related to the Mohr-Coulomb

10 theory of failure of soil, that has nothing to do with

11 the interfacial condition, because at the interface

12 all is required is to prescribe the amount of

13 frictional resistance in terms of coefficient of

14 friction.

15 BY MS. NAKAHARA:

16 Q In your model, correct?

17 A Yes.

18 Q But you could use a different formula to

19 model the interface, correct?

20 A So far as I know that is probably the

21 practice that people have been used to simulate the

22 physical phenomena of sliding friction between two

23 bodies --

24 Q But is there -- I'm sorry.

25 MR. TURK: I'm sorry, I didn't hear the

1 end of the answer.

2 THE WITNESS: For years.

3 BY MS. NAKAHARA:

4 Q But if you are not simulating a sliding

5 friction of two frictional materials, wouldn't you use

6 a different formula to represent the cohesive, the

7 interface conditions?

8 MR. TURK: Do you understand that

9 question?

10 THE WITNESS: If I have to answer I have

11 to modify the question. So would you like to replace

12 the question?

13 BY MS. NAKAHARA:

14 Q If you are not modeling a purely

15 frictional material, wouldn't you use another formula

16 to simulate the interface between -- to simulate the

17 interface conditions?

18 A I think what I sense is still the

19 fundamental problem, how to describe a physical

20 phenomena at an interface between two bodies. Whether

21 that material, whether those two materials for the two

22 bodies are frictional, or with different kinds of

23 material properties, it would be reflected in the

24 numerical value for the coefficient of frictions.

25 I think in the process my observation is

1 that the coefficient of friction, in particular, is
2 less dependent on the material as compared to the
3 surface condition.
4 As a matter of fact, in the theory of
5 tripology people are using different lubricants for
6 the same material, for that purpose, only. The
7 surface condition dictates the amount of sliding
8 between two bodies, not the material.
9 Q How do you model bonding at an interface?
10 A How do I monitor bonding in a material?
11 If I --
12 MR. TURK: I'm sorry, I thought the
13 question was how do you model bonding at the
14 interface.
15 THE WITNESS: Yes. I would do exactly
16 what we have in our model. We would come up with an
17 interface with one set of nodes on one surface, and
18 another set of nodes at the other surface.
19 And then we also prescribe matching pairs
20 of contact elements. And then we let them model, go
21 through the motions that are supposed to be, if our
22 objective is to more or less simulating a bonding
23 condition at interface, we will let the model outcome
24 dictate.
25 That means if we do find out the relative

1 displacements for those two sets of contact elements
2 are very small, then our conclusion is, yes, we have
3 simulated the bonding condition at the interface.
4 BY MS. NAKAHARA:
5 Q And you did not match elements on both
6 sides of the materials, did you, in your model?
7 A Can you repeat the question?
8 Q You did not match nodes on both sides of
9 the interface in your model, is that correct?
10 A In the hierarchy of the numerical matching
11 you have to specify a set of masters, and a set of
12 slaves, okay? Depending on your choice. The
13 advancement of the finite method indicated that -- ten
14 years ago you have to match it.
15 Now I think that the numerical scheme is
16 set up that you don't have to. But it is more
17 important that you allow the non-linear behavior to
18 occur at interface.
19 So the simple answer is that we did not
20 have to match nodes at the two surface of the
21 interface, only because the advancement in the
22 numerical scheme, incorporated into the latest version
23 of the finite elements methodology.
24 Q But your last answer, it is possible to
25 match the nodes, correct?

1 A Yes, because if you are trying to go
2 through the matching process the size of the model
3 would be so much bigger, and it would not -- it would
4 not necessarily improve the accuracy.
5 That is why sometimes it is important to
6 have the analyst have the proper experience in
7 modeling this interfacial contact behavior.
8 Q But you, yourself, have never modeled the
9 interface between the cement treated soil and clays,
10 correct?
11 MR. TURK: Other than in the PFS case?
12 THE WITNESS: I would say that, again, as
13 an analyst, to me, if we go through the proper
14 modeling at interface with contact elements, it is
15 irrelevant what kind of material that we use.
16 What is relevant, that we use a set of
17 material properties appropriate for the material at
18 the interface. And if it is done properly the proper
19 non-linear behavior would be demonstrated at the
20 interface.
21 CHAIRMAN FARRAR: Ms. Nakahara, you can
22 ask him the same question six different ways, and he
23 is going to give you the same answer.
24 MS. NAKAHARA: I understand, Your Honor.
25 CHAIRMAN FARRAR: You and your expert may

disagree with him, but this is his position, and I don't know how much benefit it gets from giving him more chances to say the same thing.

MS. NAKAHARA: I understand, Your Honor, I'm moving on.

BY MS. NAKAHARA:

Q You discussed the -- did you discuss the behavior of the cement treated soil and the clay layer, under seismic conditions, with Mr. Po Lam?

A Yes, we spent quite a bit of time trying to find out what kind of animal is this, mainly because from his experience he has not seen this material before. Mainly because it is not natural geological material, it is a man-made material.

Q But he did not evaluate the model of the interface between the two layers, correct?

A Again, the modeling of the interface has no relationship to the modeling of the material at the interface. Those are two different sets of modeling concerns.

Q If you would look at Staff exhibit YY, the plots that you developed and presented today, isn't it true that the displacement, the relative displacement between the concrete pad and the soil cement show the dissipation of energy?

1 MR. TURK: Showed the dissipation of
2 energy?
3 MS. NAKAHARA: Yes.
4 THE WITNESS: Yes. Again, we do have
5 relative displacements between the bottom of the pad
6 and the top of the cement treated soil, but the same
7 issues holds true, the durations for this relative
8 displacements occurred in a very, very short time
9 durations.
10 What that simply means is that if you look
11 at the concept of impulse, is the force times delta T.
12 If the delta T is small, what that simply means is
13 that the amount of energy consumed in the process is
14 neglectively small, mainly because the delta T is very
15 small.
16 Q Did you evaluate or plot the relative
17 displacements between the cement treated soil layer
18 and the clay layer for any case?
19 A Not for this case. But we did consider
20 the case for Hatch and San Onofree. We found out the
21 relative displacement between, for those two sites,
22 since they don't have cement treated soil the contact
23 is between the bottom of the pad, and the top of the
24 soil foundations.
25 There is no significant relative

1 displacements at the interface.

2 Q But the answer is you did not evaluate the

3 relative displacements between the cement treated soil

4 layer and the clay layer,. correct?

5 A No, we did, but I did not have time to

6 plot out the results, if that is what you mean. In

7 the process of developing the site specific model for

8 the Private Fuel Storage cask, we went into all the

9 details at every layer, also at every interface.

10 Then it is our conclusion that our model

11 is appropriate for this site. So the short answer to

12 your question is yes.

13 Q And what did you -- what were the maximum

14 relative displacements you saw for the 2000 year

15 return period at the PFS site, with the coefficient of

16 friction Mu2 of .31?

17 MR. TURK: And this is between the cement

18 treated soil and the soils below?

19 MS. NAKAHARA: Yes, and the clay layer.

20 THE WITNESS: I think we found out that

21 the amount of relative displacements at this interface

22 is also neglectively small. That is actually the

23 reason why I said, earlier, that it is the conclusions

24 from the team, with the support from the NRC Staff,

25 that it is probably adequate to assign a coefficient

1 of friction of 1.0 at interface between the base of
2 the concrete pad and the top of the soil foundations.
3 Because regardless what we put there there
4 is not movement. There is not much relative sliding
5 at the interface.
6 Q And did you provide any hard copy data to
7 the NRC Staff concerning the relative displacements
8 between -- at the interface?
9 MR. TURK: Between the cement treated soil
10 and the soils below, correct?
11 MS. NAKAHARA: Or any.
12 MR. TURK: Well, no --
13 MS. NAKAHARA: Any data between the
14 interfaces.
15 THE WITNESS: I think we talk about a lot
16 of things. We give NRC Staff a lot of information. It
17 is probably fairly early on that we go through
18 detailed discussions of that, and it is probably not
19 site specific.
20 Because when we first started this
21 project, three years ago, the first approach is a
22 generic analysis. And in that way, yes, we shared a
23 lot of information.
24 BY MS. NAKAHARA:
25 Q This is written for them, or orally?

1 A I think all the things that we communicate
2 are in a written form, but the question as to whether
3 it is formal or informal. Most of the work that we --
4 most of our research that we communicated with our
5 sponsor as informal.
6 MS. NAKAHARA: Your Honor, we have not
7 seen any of this data.
8 MR. TURK: Yes. I note that I haven't
9 either, Ms. Nakahara.
10 MS. NAKAHARA: Pardon me?
11 MR. TURK: I have not seen it either.
12 MS. NAKAHARA: I don't believe that, at
13 least you have a duty to provide discovery documents.
14 MR. TURK: Your Honor --
15 CHAIRMAN FARRAR: Wait. What if anything
16 does the State want us to do?
17 MS. NAKAHARA: At this late stage, Your
18 Honor, nothing.
19 CHAIRMAN FARRAR: The issue is that Dr.
20 Luk has some data which wasn't turned over here, is
21 what you --
22 MS. NAKAHARA: Some -- he is implying
23 supports their decision to use the interface formula
24 with the 1.0 coefficient of friction.
25 CHAIRMAN FARRAR: Mr. Turk when you said

1 you haven't seen it, do you mean by that you
2 personally, or are you representing your client never
3 saw it?
4 MR. TURK: . I'm stating a personal
5 condition. May I explain?
6 CHAIRMAN FARRAR: Yes.
7 MR. TURK: The witness described this as
8 being material that related to the generic, not the
9 PFS site specific study. Now, perhaps if the State
10 had asked us, give us everything related to the
11 generic study, we would have understood that is what
12 they wanted.
13 We provided documentation concerning the
14 site specific study, which I thought was the issue in
15 this case. Secondly, let me note that what Dr. Luk is
16 describing here is the Mu factor between the -- excuse
17 me.
18 The Mu factor that would apply in those
19 generic cases, rather than to this facility. We have
20 provided information to the State about the Mu factor
21 used specifically with respect to this facility.
22 So, number one, I don't understand that we
23 have had a previous request in discovery for this
24 material. Second, I think that we have provided to the
25 State the relevant information pertaining to this site

1 specific application.

2 CHAIRMAN FARRAR: When you say generic,

3 what does that mean?

4 MR. TURK: The witness used that term.

5 CHAIRMAN FARRAR: But what is the generic,

6 as you see it --

7 MR. TURK: When Dr. Luk began his studies,

8 as his testimony indicated previously, he was doing a

9 generic evaluation of cask stability, that was not

10 done with respect to any particular location. And he

11 added the San Onofree, and the Hatch, and then the PFS

12 sites as site specific consideration to be modeled.

13 And what he is describing, as I understand

14 it now, is information that he shared, incidently not

15 with the spent fuel project office, but with the

16 office of research, concerning his generic modeling

17 effort, before the site specific applications were

18 introduced.

19 And if I'm wrong I would ask Dr. Luk to

20 correct my understanding.

21 JUDGE LAM: So the work was done to

22 support a program, by the office of research, it had

23 nothing to do with the current litigation?

24 MR. TURK: That is my understanding of Dr.

25 Luk's testimony.

1 THE WITNESS: Yes, sir. Our direct
2 sponsor from NRC is the regulatory research group,
3 instead of the NMSS. NMSS is actually the customer
4 for the research group at the NRC.
5 MS. NAKAHARA: Your Honor -- go ahead, I'm
6 sorry.
7 CHAIRMAN FARRAR: Let me show if I
8 understand how discovery worked in this case. So if
9 a party asks for discovery of documents relating to
10 cask stability at PFS, and some of the work that
11 underlies cask stability at PFS was done on a generic
12 basis, the party is not required to turn over the
13 generic information, even though it formed basis for
14 what was done at PFS, is that how discovery works
15 these days?
16 MR. TURK: Discovery works that whoever
17 wants to obtain materials put out a specific discovery
18 request. I'm not aware that Ms. Nakahara is referring
19 to any specific request that she currently implies
20 that we failed to satisfy our obligations.
21 If she can point to a specific request
22 then I can consider whether or not we met our
23 obligation. But I'm not aware of a request that would
24 have covered those generic materials.
25 MS. NAKAHARA: We have a generic discovery

1 request for documents, in which an expert witness
2 relies on, and the generic model is the basis for the
3 model that Dr. Luk used in the PFS case. And as he
4 just testified, is the basis for him continuing to use
5 the interface model which he used at PFS.
6 CHAIRMAN FARRAR: Mr. Gaukler, you have --
7 MR. GAUKLER: Let me just say that an
8 expert can rely on his past experience, and if you say
9 an expert has to produce every document of every
10 experience he has ever been involved in, the case
11 would never get over with.
12 Here Dr. Luk provided all the materials on
13 the PFS case, he also provided the reports on San
14 Onofree, Hatch, etcetera. And to the extent that he,
15 he has a lot of modeling experience that he is relying
16 upon, and he is talking about one part of that
17 modeling experience right now, I don't think there is
18 necessarily a right to discovery in terms of every
19 document that forms the basis of his experience.
20 CHAIRMAN FARRAR: That principle is
21 unexceptional, but looking here, the suggestion that
22 the facts are somewhat different, that there was a
23 generic project that got converted into this project.
24 And that sounds like an argument that the
25 generic isn't just background information that forms

1 the basis for general expertise but, in fact, was the
2 genesis of the specific project.
3 MR. TURK: Your Honor, may I? We are
4 sitting here, June 19th, we produced Dr. Luk's report
5 back in March, March 8th was the production of the
6 entire report, other than two tables that came later.
7 If there was a concern that the State
8 thought they weren't getting enough discovery
9 materials from us, in April when I was producing
10 documents, they could have expressed it at that time.
11 I haven't heard, until this date, as
12 Hearings are in the verge of closing, that the State
13 believes that there is some other discovery material
14 that they should have been provided.
15 I think it is a late date to ask for that,
16 it is unfair to us, it is unfair to the Proceeding,
17 and to the Commission's obligation for a timely and
18 efficient conclusion of adjudicatory hearings.
19 And I think the State had an obligation to
20 determine that there was something else they wanted,
21 and to inform us before this date, as we sit in the
22 Hearings.
23 MS. NAKAHARA: Your Honor, we --
24 CHAIRMAN FARRAR: Mr. Turk, given the
25 timing of the Luk report, if I were you, I would not

1 be anxious to be pressing timing issues on this Board.

2 MS. NAKAHARA: In addition, Your Honor, on

3 January 31st, 2000, the State posed a specific request

4 to the Staff. To the extent the Staff is relying on

5 a specific caskability analysis to support its

6 justification of the request condition on using the

7 2000 year return period intervals, please produce

8 copies of those analyses for cask tipover.

9 We did not get the Luk report until March

10 8th, the final was April 2nd, revisions have come

11 since. And, as Dr. Luk has testified, he had final

12 results for the 2000 year return period in the fall of

13 2001.

14 MR. GAUKLER: I would just like to add a

15 few points, Your Honor. First of all, the State has

16 known about the generic program for some time. And

17 this is the first time they raised it, because it did

18 come up in terms, I believe, it was in Dr. Luk's

19 deposition, and it came up at the Hearing we had when

20 Dr. Luk was first -- because he talked about the

21 generic program, how that program evolved into the

22 site specific analysis that he has done, okay?

23 So in that sense they have known about

24 this for some time. And to say they felt they had not

25 received all the documents, they should have received

1 documents with respect to the generic program, I think
2 they should have raised it at that point in time, when
3 they certainly were aware of it. They certainly were
4 aware of it as of May 6th and May 7th, when Dr. Luk
5 testified.
6 Second, we are here at issue, where the
7 State raised in rebuttal, in terms of the appropriate
8 Mu factor, so it is one that the parties may not have
9 focused on before. I mean, in that sense we are
10 looking at an issue that was raised, through nobody's
11 fault.
12 But I'm saying that I don't think that --
13 they are saying that somehow, that discovery has
14 improperly withheld, I don't think it translates into
15 that.
16 MR. TURK: And may I note, also, Your
17 Honor the issues that we are addressing in part D were
18 admitted by the Board's order in December of 2001.
19 That is when the QQ portion of this Contention was
20 admitted. That is Part D of the Contention, as well
21 as Part C, if I'm not mistaken.
22 So in terms of timing, we went through
23 this previously with respect to the decision that we
24 made that we would want Dr. Luk to participate in this
25 Proceeding.

1 We then asked for him to conclude the
2 report, and to get it to us. We produced it to the
3 Staff, we gave the State the specific information
4 relevant to the PFS site specific application.
5 The State is suggesting that because they
6 have filed a discovery request, virtually two years
7 before the Board's ruling, places an obligation on us
8 to produce generic materials, long ago, that were not
9 specifically related to the PFS site specific report,
10 I think strains the parties interpretation of
11 discovery applications.
12 I second Mr. Gaukler's comments about the
13 fact that the generic issue could have been identified
14 previously by the State, and they did not do so until
15 today.
16 MS. NAKAHARA: Are you saying you don't
17 have a duty to supplement discovery responses?
18 CHAIRMAN FARRAR: We've learned what we
19 can about this. Let me talk to my colleagues.
20 (Judges conferring.)
21 CHAIRMAN FARRAR: We don't think this is
22 something we can sort out today, nor would it be a
23 good use of time to pursue this further now.
24 If upon reflection, after the Hearing is
25 over, the State thinks there is some action they would

1 like to ask for, they like anybody else, is free to do
2 that.
3 MS. NAKAHARA: Thank you, Your Honor.
4 BY MS. NAKAHARA:
5 Q Dr. Luk, a follow-up to your testimony
6 about modeling soil conditions related to your weapons
7 experience. Have you modeled the stress-strain
8 relationship of the clay previously?
9 A We include a wide spectrum of natural
10 geological material. So, again, like I said, the
11 different category of natural geological material is
12 reflected by the material properties that we use.
13 Since I'm not trained in the geotech area,
14 I actually relied on experts in that area to make sure
15 that what I input has the material properties for
16 those materials are correct.
17 Q Dr. Luk, isn't it true at one time the
18 review panel for the generic project had a concern
19 that the moisture content at surfaces is a dominating
20 factor that affects significantly on the coefficient
21 of friction for sliding behavior of casks?
22 A If you don't mind me, I will modify the
23 question a little bit. Yes, we did consider the
24 surface condition at the interface. Moisture content
25 is one of the issues that we brought up.

1 But I don't know whether it is -- we
2 consider that as a dominating factor. It is one of
3 the factors which would influence the chosen
4 coefficient of friction at the interface.
5 Q And how did you address any concerns with
6 the moisture content at the interfaces model at the
7 PFS site?
8 A I'm referring to the analysis report.
9 We know for concrete to concrete contact at interface,
10 the nominal value from the existing data base is
11 something of the order between 0.5 and 0.6.
12 And we, intentionally, lower the nominal
13 value to 0.20 as basically trying to include the
14 possibility that there will be moisture content at the
15 interface between the base of the pad and -- the base
16 of the cask and the top of the concrete pad.
17 Q And is the moisture content at the
18 interface between the bottom of the concrete pad, and
19 the top of the cement treated soil layer a concern?
20 MR. TURK: A concern to whom?
21 MS. NAKAHARA: To Dr. Luk.
22 THE WITNESS: In a way that is the reason
23 why we also choose at this interface, in particular,
24 the coefficient of friction equals 2.31. This is the
25 upper bound is 1.0.

1 But, also, we are still trying to simulate
2 a physical conditions. The interface between the
3 bottom of the cask and the top of the pad seems,
4 because it is exposed to atmosphere, there is a strong
5 likelihood that there will be moisture at interface.
6 But as to the interface between the bottom
7 of the cask and the top of the commitments, from the
8 engineering perspective, the amount of moisture would
9 be significantly limited, mainly because it is not
10 exposed to atmosphere.
11 I'm still trying to answer the questions
12 from the engineer perspective. We are trying to
13 simulate, we are trying to solve a engineering
14 problems by simulating with an engineering model.
15 Q So are you confident that your interface
16 at the bottom of the cask and the top of the concrete
17 storage pad adequately accounts for moisture?
18 MR. TURK: And when you say that do you
19 mean with respect to his use of a lower coefficient of
20 friction?
21 MS. NAKAHARA: Yes.
22 THE WITNESS: In a way that when we
23 discussed with the project team, as well as with the
24 NRC Staff, it is the consensus, yes.
25 BY MS. NAKAHARA:

1 Q When you say consensus, did anybody
2 disagree?
3 A No.
4 Q Earlier you testified that you and Dr.
5 Shaw picked a 270,000 PSI for the cement treated soil
6 or the soil layer beneath the storage pad for a
7 Young's modulus, correct?
8 A Yes.
9 Q And when the maximum Young's modulus, when
10 the maximum allowable Young's modulus for the cement
11 treated soil layer, as posed by the criteria to ensure
12 the integrity of the canister at 75,000 PSIs, why did
13 you pick 270,000?
14 MR. TURK: Objection, it has been asked
15 and answered already.
16 MS. NAKAHARA: It has not been asked and
17 answered.
18 MR. TURK: I asked him why he used a
19 270,000 and he answered.
20 MS. NAKAHARA: He said it was --
21 CHAIRMAN FARRAR: Wait, wait, wait. The
22 fact that you asked him doesn't mean she can't ask
23 him. You were on direct, this is cross.
24 THE WITNESS: Yes, I will reiterate what
25 I said.

1 BY MS. NAKAHARA:

2 Q Can I interject? I understand you said it
3 was to be conservative. But why did you pick a
4 270,000 number, when 75,000 is the maximum it could
5 be?

6 A Well, the answer is that this is the
7 number that was given to Sandia by Dr. Mahendra Shaw.
8 But also in the process we discussed the relative
9 technical merits of why we use a high Young's modulus.

10 And in the process we say, okay, if we are
11 going to generate a conservative solution in terms of
12 the seismic response of the cask, it is not bad. But
13 we also find out, from our modeling experience, in
14 particular the response for the dry cask, that cask
15 behavior is not very sensitive to a selection of the
16 Young's modulus for a given layer of soil.

17 And in that regard after evaluations we
18 agreed with the selections from Dr. Mahendra Shaw.

19 Q Do you know the basis of the 270,000 PSI
20 that Dr. Shaw gave you?

21 A I cannot recollect the references from
22 which this selection was made.

23 Q Would you repeat that? I'm sorry.

24 A I do not recollect the rationale behind
25 the selections of 270,000 PSI for the Young's modulus.

1 Q Were you aware that the cement treated
2 soil had and, again maximum value of 75,000 PSI for
3 the Young's modulus at the time that you selected the
4 270,000 PSI value?
5 MR. TURK: In the Applicant's design?
6 THE WITNESS: I was informed informally.
7 BY MS. NAKAHARA:
8 Q Did Mr. Po Lam review the value that you
9 selected for Young's modulus to the cement treated
10 soil?
11 A Yes, all the material properties tabulated
12 in tables 2 to 7 are needed in going through the
13 process. And are also needed when we develop the soil
14 foundation model. So Mr. Po Lam was given the set of
15 informations as I was given by Dr. Mahendra Shaw.
16 Q And did Mr. Po Lam voice an opinion that
17 the 270,000 PSI was representative of the maximum
18 value of 75,000 PSI for a Young's modulus value?
19 MR. TURK: Objection to the form of the
20 question. The question was that did Mr. Lam agree
21 that it is representative of 75,000.
22 MS. NAKAHARA: That is fine, I will just
23 withdraw it.
24 BY MS. NAKAHARA:
25 Q In response to Judge Lam and Mr. Turk, you

1 referred to shake table data for --

2 CHAIRMAN FARRAR: Wait, I must admit to

3 being mystified here. The number that is going to be

4 used is 75,000, you have all the justification in the

5 world for using 270,000, why would you use it?

6 I mean, maybe I'm really missing something

7 here. I mean, you can say it is conservative, you can

8 say it doesn't make a difference, but why would you do

9 it?

10 JUDGE LAM: Before Dr. Luk could answer,

11 perhaps Mr. Turk can shed some light on this. Mr.

12 Turk?

13 CHAIRMAN FARRAR: While Mr. Turk is -- Dr.

14 Luk, you cannot shed light, that is the number you

15 were given?

16 THE WITNESS: Well, also I think it has

17 reference to some report, but I did not actually spend

18 a lot of time on the report. That is the reason why

19 I said I could not recollect.

20 CHAIRMAN FARRAR: You mean there was some

21 report about this project that suggested they might

22 use 270,000 as the number, or some -- I mean, I don't

23 get it.

24 THE WITNESS: Yes. I think the -- I much

25 prefer if Mr. Turk can answer the question.

1 CHAIRMAN FARRAR: Okay. But before he
2 does, you didn't say, when they handed you this
3 number, you didn't say wait a minute, this is nuts?
4 THE WITNESS: Well, the -- this is what I
5 did with Po Lam. When we are given this set of
6 material, in particular with either the soil cement
7 layer, which is adjacent to the concrete pad, or the
8 cement treated soil underneath the pad, we basically
9 raised the question, what is this?
10 Because it is man made material, okay? We
11 asked for clarifications. And then I was told by Dr.
12 Mahendra Shaw, they are not natural soil type. And
13 because of that it will be very difficult for us to
14 use our knowledge based on natural geological material
15 to evaluate the appropriateness of using these kind of
16 values.
17 CHAIRMAN FARRAR: So at that point, in
18 your mind, you had done all you could, and now here is
19 the number, they gave it to you, you are hired to do
20 a job, so you did it?
21 THE WITNESS: Yes, but it is also we find
22 out, we are not going to spend a lot of time on those
23 material properties, which has no significant
24 contribution to the analysis results.
25 JUDGE LAM: So you trust, but verify?

1 THE WITNESS: Yes.

2 JUDGE LAM: I think the record would

3 benefit from an explanation from Mr. Turk's witness,

4 Dr. Shaw is here, then perhaps -- of selecting 270,000

5 PSI for Young's modulus by the Staff, would be

6 beneficial to us.

7 MR. TURK: May I have a moment to consult?

8 JUDGE LAM: Yes.

9 (Pause.)

10 MR. TURK: Your Honor, I have consulted

11 with Dr. Shaw, as well as with Mr. Pomerening. I'm

12 informed by Dr. Shaw that he had reviewed literature

13 in which a 270,000 PSI Young's modulus was discussed

14 with respect to soil cement.

15 And he decided to utilize that value

16 because it was referenced in the literature, and

17 because it would represent a conservative bounding

18 condition for the Young's modulus.

19 So when Dr. Luk would be conducting his

20 analysis, in the interest of finding cask displacement

21 without understating the cask displacement, or the

22 cask rotation, use of that modulus would server the

23 purpose of being conservative to assure that we

24 weren't going to underestimate cask rotation and

25 displacement.

1 CHAIRMAN FARRAR: Thank you for that
2 explanation. I guess that raises the question that I
3 think has been discussed in the testimony. When you
4 are doing these dynamic, complicated analysis, how do
5 you know that something is conservative?
6 I mean, simple example. The harder I step
7 on my brakes the sooner I stop, unless I'm on ice. I
8 mean, how do we know there is an unless factor here
9 that when you say you are using something that seems
10 like it is conservative, but in all the interaction of
11 these factors it turns out not to be conservative?
12 That is an inartful way of raising the
13 question, but I think you understand what I'm getting
14 at.
15 MR. TURK: Well, I can only state, as a
16 non-witness Your Honor, and I think maybe Dr. Luk is
17 the one to answer. But I understand his model to be
18 an attempt to do a realistic modeling. There was the
19 insertion of this conservativism, as well as the two
20 foot cement treated soil depth, as a conservativism
21 that we discussed before.
22 So it is a realistic model with these
23 conservative elements inserted into it. And Dr. Luk
24 indicated he didn't see a significant change in the
25 displacements, based upon the variance of Young's

1 modulus, as I understand his testimony.

2 THE WITNESS: Can I provide some input

3 here?

4 CHAIRMAN FARRAR: Yes, go ahead.

5 THE WITNESS: Okay. When people modeling

6 soil foundations, the soil behavior is more sensitive

7 to shear modulus than Young's modulus. Young's

8 modulus is the -- it is different from the shear mod

9 mainly because it is the normal, it is the slope of a

10 plot of normal stress versus normal strain.

11 And in that sense for soil behavior, soil

12 behavior is a small dominated by shear modulus, than

13 Young's modulus. That means it is more shear type of

14 deformation in soil than the pressing or pushing.

15 And in that regard it is confirmed by our

16 analysis results that the soil behavior is not very

17 sensitive to the selection of Yom.

18 CHAIRMAN FARRAR: But is it not possible

19 that if you select what you think is a very

20 conservative Young's modulus, that somehow in all the

21 modeling and interaction of the different factors,

22 that it has the reverse effect than you thought it was

23 going to have?

24 I mean, I take it in non-linear analyses

25 that is a problem, that the variables --

1 THE WITNESS: Your Honor, you are correct.
2 In a non-linear world sometimes it is hard to see the
3 outcome. But I think through our experience, that we
4 do go through some sensitivity evaluations, and is
5 confirmed.
6 The soil behavior is more or less
7 dominated by shear deformation in terms of shear
8 modulus, than a normal stress and strain that is
9 represented by Young's modulus.
10 JUDGE LAM: Dr. Luk, what is the range of
11 the Young's modulus in your sensitivity study?
12 THE WITNESS: I think the range of the
13 sensitivity, I have to refer back to the other site
14 specific calculations. But let me also remind you, if
15 you go to tables 2 to 7, you can look at the variation
16 of the Young's modulus.
17 At the lower end we have 20,000 PSI, okay?
18 BY MS. NAKAHARA:
19 Q Dr. Luk, on what page?
20 A This is on page 10.
21 Q Thank you.
22 A But a Young's modulus for the aggregates
23 is 20,000 PSI. And if you go to the bottom of our,
24 bottom layer of our soil foundations, it has a value
25 of 612,000 PSI.

1 So the range of Young's modulus varies a
2 lot.
3 JUDGE LAM: But what I meant was, when you
4 did your sensitivity study regarding the 270,000
5 Young's modulus for this cement treated soil, I was
6 assuming you did a sensitivity study by changing that
7 particular Young's modulus value to confirm that it
8 really doesn't matter that much, since you are
9 exceeding the maximum allowable Young's modulus of
10 75,000 by quite a bit.
11 Now, is that a true assumption, or are you
12 just saying that, well, based on table 2 to 4, or 2 to
13 7, that it indicate there is a wide range of Young's
14 modulus, which is a different study?
15 THE WITNESS: Okay. We do the sensitivity
16 study through Po Lam's effort, because he is the one
17 primarily responsible for developing the soil
18 foundation model.
19 And if you recollect our model is an
20 engineering approach for a more complicated layer
21 separations for the site specific soil profile data.
22 They actually have a lot more horizontal layers than
23 what we have in our model.
24 But we want to make our model more
25 efficient, that is why we more or less are going

1 through the consolidation process, try to lump the few
2 horizontal layers in the soil profile data into one.
3 And in that process the sensitivity of the
4 selections, or what should be used for the given layer
5 that we incorporate in our soil foundation, as that
6 should be reflected in the soil behavior.
7 So sensitivity was performed in that way.
8 JUDGE LAM: But the fact of the matter is
9 you did not perform a study using 75,000 PSI Young's
10 modulus for the cement treated soil?
11 THE WITNESS: Yes, sir.
12 CHAIRMAN FARRAR: Yes, you did not?
13 THE WITNESS: Correct.
14 CHAIRMAN FARRAR: It is 12 after 6, and
15 Mr. Gaukler, when I said good job I forgot that the
16 transcript doesn't record the time that you came in 4
17 minutes under 15 alloted. But here we are,
18 notwithstanding that, close to quarter after 6.
19 How much more does the State have?
20 MS. NAKAHARA: I don't have much left,
21 maybe 15 minutes if I talk fast, 20. That is actually
22 probably an overestimate.
23 CHAIRMAN FARRAR: Well, it is 13 after,
24 let's take a 7 minute break, be back here at 20 after.
25 (Whereupon, the above-entitled matter

1 went off the record at 6:13 p.m. and
2 went back on the record at 6:22 p.m.)
3 CHAIRMAN FARRAR: Unless the Staff and
4 Applicant would have very brief redirect we will just
5 hold that over until tomorrow. Mr. Turk, is Dr. Luk
6 trying to get out of town?
7 MR. TURK: He has a four o'clock plane.
8 CHAIRMAN FARRAR: Tomorrow.
9 MR. TURK: Tomorrow, which means we need
10 to let him go at one o'clockish.
11 CHAIRMAN FARRAR: All right.
12 MR. TURK: I don't know if Dr. Bartlett
13 intends any surrebuttal. Can I ask him how long that
14 might take?
15 MS. NAKAHARA: Ten minutes, 15 minutes,
16 very brief. But we are really pushing ourselves,
17 then.
18 CHAIRMAN FARRAR: Right. But we are going
19 to finish on schedule this week. Go ahead, Ms.
20 Nakahara.
21 MS. NAKAHARA: Thank you, Your Honor.
22 BY MS. NAKAHARA:
23 Q Following up on Judge Lam's question, Dr.
24 Luk, isn't it true you had not conducted any
25 sensitivity analysis with your model using three

1 different interfaces?

2 In the PFS, to model the PFS site, isn't

3 it correct you modeled three different interfaces?

4 A Yes.

5 Q You have not conducted a parametric study

6 with a model with three different interfaces, have

7 you? Any type of parametric study?

8 A Not yet.

9 Q In response to questions from Mr. Turk,

10 and Judge Lam, you mentioned shake table data from

11 Japan, is that correct?

12 A Yes. Those are not the quantitative data.

13 They put a house on a shake table, and you can

14 actually see the house move, physically.

15 Q What size is the house?

16 A Miniature. Yes, they do that very, very

17 often, as a demonstration to the public.

18 CHAIRMAN FARRAR: What does that mean,

19 miniature?

20 THE WITNESS: Subscale.

21 CHAIRMAN FARRAR: Right, but how sub, how

22 big a house to start with, and how sub a scale? I

23 mean, does it end up as a big as a dog house, or as

24 big as a little cottage, or --

25 THE WITNESS: Well, I think some of the

1 shake table they are talking about is maybe, it is a
2 shake table that I was told is maybe eight meter by
3 eight meter.
4 And then so you have the size may be
5 smaller than that, you may have a four meter by four
6 meter, for example. And then you have miniaturized
7 furniture.
8 CHAIRMAN FARRAR: Okay.
9 THE WITNESS: So it is not real, really
10 small, but it is not the full size.
11 BY MS. NAKAHARA:
12 Q And isn't it true at one time the review
13 panel for your generic project posed, as one of its
14 goal, is to perform a finite element analysis using
15 CIRPER data, which is the Japanese data?
16 A Yes, that is -- that test was conducted
17 either late in the '80s, or early '90s.
18 Q And that is with the house, correct?
19 A No, I'm sorry. This is with one foot and
20 a one fifth of a dry cask on the surface of the shake
21 tables. So it does not include the soil structure,
22 soil structure interactions.
23 It is just a cask on top of steel surface.
24 Q And did you validate any portions of your
25 model with that CIRPER data?

1 A We did not. The answer -- they only
2 applied one horizontal citations. But in our model we
3 simultaneously applied three seismic citations. That
4 is why we don't think it is adequate to go through
5 that.
6 But the primary reason is that the NRC
7 Staff have approached, many times, have tried to get
8 that test data from CIRPER in Japan. And we were told
9 we would have to pay, we means the NRC have to pay a
10 significant portion of money to get that set of data.
11 And since it is only for one dimensional
12 seismic citations, the decision from the NRC Staff is
13 that the amount of money they ask does not merit to
14 pay the money to get the data.
15 So in that rate our model has not been
16 validated by this set of test data.
17 Q And earlier did you testify that you were
18 more concerned about the effect of shear modulus in
19 your model, than Young's modulus, is that correct?
20 A Yes.
21 Q Isn't shear modulus a function of Young's
22 modulus?
23 A No, they are two different phenomena, they
24 are independent of each other.
25 Q Isn't it true that shear modulus and

1 Young's modulus are related by Poisson's ratio?

2 A The -- in a way that is correct. But I

3 think the Poisson's ratio, by its straight technical

4 definitions, is only related either to stress, or

5 strain.

6 But it would be -- yes, in a way it is

7 correct.

8 Q What shear modulus did you use for the

9 cement treated soil layer?

10 A I have to refer back to one of the

11 submittal. I note in tables 2 to 7 we did not include

12 a shear modulus. But if you allow me, Your Honor, I

13 make reference to one of the submittals related to the

14 Private site storage cask analysis, which is the

15 submittal to me by Mr. Po Lam.

16 And they do have a table, table 1, which

17 has all the detail parameters that is incorporated

18 into the soil foundation model. And I don't have the

19 page number, but it is actually shown here.

20 MR. TURK: Could we just identify what

21 document it is that Dr. Luk has handed to counsel for

22 the State?

23 MS. NAKAHARA: This is the analysis of

24 soil foundations at Private Fuel Storage facility.

25 MR. TURK: Does it bear a date and the

1 page number, please.

2 MS. NAKAHARA: Dated August 27th, 2001.

3 THE WITNESS: You have that as one of the

4 documents that we --

5 MS. NAKAHARA: Your Honor, I don't think

6 we've seen this.

7 MR. TURK: I've seen several Po Lam

8 reports which were produced to the State. I don't

9 know a specific one, but I've seen two or three.

10 What page is that?

11 MS. NAKAHARA: There is no page, it is

12 table 1, it is after the references, after the report,

13 the first page after the references in the report.

14 MR. TURK: Your Honor, I believe the State

15 is incorrect in saying they haven't seen this before.

16 We produced, for the State, a set of three memos from

17 Po Lam, with different dates. My understanding is

18 that this is one of the three that we produced to

19 them.

20 MR. GAUKLER: I recall receiving three

21 memos.

22 CHAIRMAN FARRAR: Sort that out later, and

23 just continue with the questioning on it.

24 BY MS. NAKAHARA:

25 Q Dr. Luk, is it correct you stated, in

1 response to questions, I'm not sure if it was Mr.
2 Turk, or Mr. Gaukler, with respect to the plots in
3 Staff YY, that you had so many data points, that you
4 skipped some, did I misunderstand that?
5 A No, let me try to explain a little bit.
6 MR. TURK: I'm sorry, no, she is not
7 correct? She asked you is she -- I'm sorry. Could
8 I ask for the last question to be reread?
9 CHAIRMAN FARRAR: Do you understand the
10 question?
11 THE WITNESS: Yes.
12 CHAIRMAN FARRAR: Just answer, and don't
13 worry whether it is a yes or no, just tell us the
14 answer.
15 THE WITNESS: Since they have so many
16 calculations, the 7.5 times 10 to the 5th
17 calculations. So in the process for us to go through
18 the evaluations we sometimes choose, we are going to
19 look at the analysis results at every 100th step,
20 okay?
21 So in that regard we think that durations
22 of the 100 calculations, there is not much change. So
23 that is a conventional practice, to try to -- actually
24 try to manage the data base, so that we will get a
25 good representation of the results.

1 So in that way, in your terminology is
2 skipping, but skipping simply means if we look at the
3 results at every time step, the output would be so
4 humongous, it would be very hard to deal with.
5 CHAIRMAN FARRAR: But you are not
6 choosing, you are saying take every hundredth,
7 whatever it is?
8 THE WITNESS: Yes, sir.
9 CHAIRMAN FARRAR: Okay.
10 BY MS. NAKAHARA:
11 Q And what time value does hundred steps
12 correlate?
13 A Well, we know one delta T was the four
14 times 10 to the minus 5 second. So if you have the
15 times by a hundred, so it should be 4 times 10 to the
16 minus 3 second.
17 Q Okay.
18 A So that is still very, very small.
19 Q And in response to questions from Mr.
20 Turk, is it correct that you testified earlier that
21 you are aware of the site specific soil parameters at
22 the PFS site?
23 A Yes, I was told the site specific soil
24 profile data that given to me, was the one that was
25 appropriate for the Private Storage site.

1 Q But you, yourself, do not know that, is
2 that correct?
3 MR. TURK: Your Honor, I'm going to
4 object. This is the same question that she asked the
5 last time Dr. Luk appeared, when the State was
6 attempting to characterize his knowledge as being
7 simply accepting at face value.
8 Dr. Luk specifically stated he did not
9 independently verify the data. I don't know what we
10 are accomplishing by retreading old ground.
11 MS. NAKAHARA: That is just what I'm
12 following up on. He said he was aware.
13 MR. TURK: Asked and answered.
14 MS. NAKAHARA: You asked today, he
15 answered on May 6th.
16 CHAIRMAN FARRAR: The objection is
17 overruled, go ahead.
18 THE WITNESS: After we were given the site
19 specific soil profile --
20 CHAIRMAN FARRAR: Just a minute.
21 MS. NAKAHARA: How about if I ask it this
22 way?
23 CHAIRMAN FARRAR: Just a minute. We know
24 it is late, but let's make sure everyone observes the
25 decorum of the Hearing. Go ahead, Ms. Nakahara.

1 BY MS. NAKAHARA:

2 Q Dr. Luk, to try and speed this up, have
3 any responses that you gave on May 6th and 7th, with
4 your personal knowledge of the site specific
5 conditions at the PFS site for soil parameters,
6 changed today?

7 A No.

8 Q Thank you. And has any of your testimony
9 that you gave today, changed any of your previous
10 testimony, written or oral, that you've given in this
11 Proceeding?

12 A No.

13 Q To the best of your knowledge?

14 A No.

15 Q Thank you.

16 MS. NAKAHARA: I have no further
17 questions, Your Honor.

18 CHAIRMAN FARRAR: Thank you, Ms. Nakahara.
19 Mr. Turk, how much does the Staff have by way of --

20 MR. TURK: Under ten minutes.

21 CHAIRMAN FARRAR: Mr. Gaukler?

22 MR. GAUKLER: I don't have much of
23 anything. I can do it either tonight or tomorrow,
24 Your Honor, whatever is your preference. Perhaps we
25 are all getting tired.

1 CHAIRMAN FARRAR: Let's both of you use
2 the evening to sharpen up and make sure your questions
3 are on point, and we will continue tomorrow at 9 a.m.
4 (Whereupon, at 6:39 p.m., the above-
5 entitled matter was concluded.)
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CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Private Fuel Storage, LLC

Docket Number: Docket No. 72-22-ISFSI

ASLBP No. 97-732-02-ISFSI

Location: Rockville, Maryland

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

/s/ John Mongoven

John Mongoven
Official Reporter
Neal R. Gross & Co., Inc.