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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE

133RD MEETING

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WEDNESDAY

MARCH 20, 2002

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The meeting commenced at 1:00 p.m. in Conference Room 2B3, Two White Flint North, Rockville, Maryland, George M. Hornberger, ACNW Chairman, presiding.

PRESENT:

GEORGE M. HORNBERGER	ACNW Chairman
B. JOHN GARRICK	ACNW Member
MILTON N. LEVENSON	ACNW Member
RAYMOND G. WYMER	ACNW Member

STAFF PRESENT:

JOHN T. LARKINS	Exec. Dir.-ACRS/ACNW
SHER BADAHUR	Assoc. Dir.-ACRS/ACNW
HOWARD J. LARSON	Spec. Asst.-ACRS/ACNW
LYNN DEERING	ACNW Staff
LATIF HAMDAN	ACNW Staff
MICHAEL LEE	ACNW Staff
RICHARD K. MAJOR	ACNW Staff

ALSO PRESENT:

SITAKANTA MOHANTY

RICHARD CODELL

I-N-D-E-X

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

(1:07 p.m.)

CHAIRMAN HORNBERGER: The meeting will come to order, the afternoon session here of the 133rd meeting of the ACNW. I have a note for the Committee. At three o'clock, we are to go over to the neighboring building to get new badges. And so we have an appointment at three o'clock. That shouldn't be a problem because we have a 2:45 to three o'clock break schedule and I don't think that I will steal so much of the time that we've given over to Dick and to Sitakanta to do a presentation.

Dick was originally scheduled to talk to us about the sensitivity studies for the waste package, and Howard tells me he's going to talk about anticipatory research instead.

(Laughter.)

Although I may be corrected and it may in fact revert back to the sensitivity studies. Sitakanta, are you going to go first or is Dick?

MR. MOHANTY: I'm going first. Good afternoon, ladies and gentlemen. My name is Sitakanta Mohanti. I will be -- myself and Dr. Richard Codell will make this presentation. I will go over the first part of the presentation, and Dr. Codell will make the

presentation on the second half of this talk.

The title of this presentation is, "Sensitivity and Uncertainty in the NRC Total System Performance Assessment of TPA 4.1 Code," I should add results. Okay. Here is an outline of this presentation. First, we will briefly address the purpose of this analysis of uncertainty and sensitivity. Then we will present an overview of the Total System Performance Assessment preliminary results. And then we will talk about the sensitivity analysis results that have been obtained so far. Then some effects of treatment of data, especially variance and uncertainty on the expected dose estimation. Then finally we will talk about the preliminary risk insights from the sensitivity and uncertainty analysis.

Under the sensitivity analysis results, that is the third bullet, we have three specific presentations: One is characterized as the parametric sensitivity analysis, then we will talk about distributional sensitivity analysis, then the third one will be with a subsystem of barrier component sensitivity analysis. I will be talking about the first two bullets, and a portion of sensitivity analysis results, especially distributional

sensitivity analysis and subsystem of barrier component sensitivity analysis.

First, here are the purposes of the analysis. As you all know, NRC staff, in conjunction with the staff from the Center for Nuclear Waste Regulatory Analysis, have been involved over several years in developing the Total System Performance Assessment Code. The TPA Code represents an independent approach to assist NRC's review of DOE's performance assessment.

NRC's performance assessment tools are intended to be used for gaining risk insights and to risk inform the pre-licensing and the potential licensing activities proactively and reactively. For example, the development of the Yucca Mountain Review Plan that you will hear about tomorrow, the development of analysis tools by various key technical user groups, or KTIs, and the confirmatory testing, all these have been and will continue to be influenced by the analysis that is performed using the Total System Performance Assessment or the TPA groups of tools.

As far as the reactor work is concerned, staff is particularly looking at improving capability to review license applications, such as DOE's

performance assessment results and probe DOE's assertion regarding the repository performance, identify probabilities, such as risk dilution. Some of these examples we will cover during the course of this presentation.

Staff will also look at DOE's sensitivity and uncertainty analysis approaches and also will try to identify by doing its independent analysis which model assumptions analysis and what is the degree of importance of all these to the overall performance. And it will also verify DOE's assertion regarding the barrier importance.

These activities will require staff's, one, understanding of the system as a whole, therefore getting into various components of the total system is very important. Therefore, staff will use these tools and knowledge in understanding the system as a whole and understand the factors that are important to safety performance.

Here I will give you just a very brief background before we move on to the results. These are also some of the caveats in the sense that you have heard about the results -- you have heard the results from TPA 3.2 sensitivity analysis in the past, and this represents the latest -- DOE's latest design,

which it designed. And we have not done any analysis using DOE's low temperature concept, because their high temperature concept is considered as the normal case.

The Total System Performance Assessment Code, or the TPA Code, currently has about 950 parameters, out of which 330 parameters are samples. So this is a pretty large problem for any kind of Monte Carlo analysis on conducting sensitivity and uncertainty analysis. So that means 620 parameters are not sample, they're fixed at constant values at what we believe as the best available value. And if necessary, those values can be varied if we want to support the current sensitivity analysis.

The results that will be presented alternative conceptual models -- the results on conceptual model analysis will not be shown for the second time. However, in the context of the Total System Performance Assessment, conceptual model studies are done on a case-by-case basis, alternative conceptual model studies.

And we would like to add the note that analysis are performed mainly for developing staff understanding, and the analysis that would be presented are not necessarily mandated by the

regulatory requirements. And the results are preliminary in the sense that this sensitivity analysis is currently under development. The report is not ready. So what you are seeing today is a snapshot of the results that we have come up with so far. The results will be perhaps finalized in several months.

Here I will start with the performance assessment results. The performance measure is the peak expected dose to the reasonably maximally exposed individual. And the results will be shown essentially for two scenarios. The first one is the nominal case scenario, which is characterized by the slow degradation over time leading to ground water release. And the disruptive events scenario only one we will present here is the igneous activity. Other two disruptive event scenarios are seismic activities as well as faulting activity. However, seismicity is included in the nominal case, whereas we are not presenting results on faulting because there is no sensitivity. We don't see more sensitivity to faulting event results.

And as far as the nominal case scenarios are concerned, essentially the risk is computed by averaging the results from Monte Carlo realizations,

which is in terms of dose as a function of time. And then the peak is determined from the expected dose curve. Whereas the disruptive event scenario requires some specialized calculations because of the low event probability. Therefore, special convolution has been used to take into consideration all possible events prior to the event time. Prior to the evaluation time, if there are events, those should be appropriately factored in so that we get a smooth risk curve.

First, this is the result of the nominal case scenario. In the figure, we are presenting dose versus time, but before we go through the figure, let me just highlight that by the time the regulation was out, was finalized, this work was already underway. Therefore, some of the things that you are seeing here are still different from what is mandated by the rule. For example, the well pumping rate is varied in these calculations. The receptor group is located at 20 kilometers. Other than that, I think these are the main ones that are different compared to the rule.

And just to highlight, what we have seen so far is that there are no corrosion failures in 10,000 years, no seismic failures in the nominal case. The nominal case is the one which is defined by

probability pretty close to one, and we are presenting here results from 350 realizations. So primarily the doses are resulting from the initially defective failure which is varied between one to 88 waste packages. To compare that, we have a total of 8,877 waste packages, with each waste package having about 7.89 MTU of spent fuel.

CHAIRMAN HORNBERGER: Sitakanta, what does that probability approximately one, what does that mean?

MR. MOHANTY: Because this is the -- okay. If we subtract the probability for the disruptive events, such as volcanism, then it's a very large number. This is number is pretty close to one.

Also, there are several important things to observe in this figure. The rate curve represents the expected dose curve, which is an arithmetic average of the individual realizations which are represented in this blue color. The dark blue color is the 95th percentile curve, and the green color represents the 75th percentile curve. What this entails is that until about 6,000 years the expected dose curve exceeds the 95th percentile. And throughout the 10,000 years, the expected dose curve exceeds the 75th percentile.

So this gives some sort of indication that the expected dose curve appears to be quite robust in determining the expected dose. And the peak expected dose is from the expected dose curve, and clearly this indicates the expected dose curve is -- expected dose arc is pretty close to 10,000 years. And to be exact, in our calculation it is showing up at 9,769 years.

MEMBER GARRICK: Now, this is just from defective failures.

MR. MOHANTY: These are all from defective failures.

MEMBER GARRICK: Because this is not the peak dose for much later times.

MR. MOHANTY: Right.

MEMBER GARRICK: Yes.

MR. MOHANTY: Okay. Corresponding to that figure, here are some additional results. The figures on the left represent the cumulative release from the saturated zone because that is the end point after the transport through the geosphere, and after that it is the biosphere. So I'll talk first between the biosphere and the geosphere. This is the release rate, and the release rate -- cumulative release rate are presented in the Y axis of this curve for 10,000 years here and 100,000 years here. And these values

are presented in large scale so that you can see these numbers which are very small, smaller than one. And because these are smaller than -- some of these are smaller than one, therefore the log of that is a negative number here.

Clearly, it shows that technetium is dominating, also iodine-129 and chlorine-36. And here is the corresponding curve. And this indicates that most of the dose, which is about 52 percent of the dose, contributes and is coming from technetium-99 and about 25 percent of the dose coming from iodine and 20 percent coming from neptunium-237, and others are sort of insignificant in terms of dose contribution.

I have just put a figure from 100,000 years just for comparison purposes. This shows that if you go beyond 10,000 years, the dominant -- the same nuclides are dominating, but you can see some finite values. You don't have to see -- there are no negative numbers here in the log space.

Next, here is the result from the disruptive event scenario, as I mentioned earlier. The faulting event -- we are not showing the results for faulting event, and the seismicity was included as part of the base case, and we did not see any failures in 10,000 years. So, essentially, this is a

comparison between the nominal case scenario and the igneous activity scenario.

So, clearly, this shows that the peak in the igneous activity scenario, which has a recurrence rate of ten to the one minus seven per year, the dose -- the peak expected dose occurs much earlier compared to the nominal case. As I mentioned earlier, in the nominal case scenario, the peak expected dose occurs close to 10,000 years.

And to obtain this smooth curve, we needed about 4,200 realizations, coupled with the convolution integral approach that one was used to obtain this curve. And this drop here is perhaps because we have not taken one step beyond 10,000 years. Because if we take a step beyond 10,000 years, this line is going to flatten out or will perhaps slightly go up.

For the early release, this peak from the igneous activity event, which is 0.35 milirems per year, that occurs at 245 years. And the dominant radionuclide is americium-241, and this dose is primarily because of high activity nuclides, which americium-241 is one of them.

Okay. Next, I will briefly go over the stability of the peak expected dose. As such, because it is an expected dose, we should expect a lot of

stability in that number. We are using 350 realizations, and we considered that to be quite stable. But I also wanted to show you some variation, what happens if we go much beyond 350 realizations. In this table, that shows that we have gone beyond 500. We have gone all the way to -- in fact, we have gone to 4,000 realizations. Here, this one shows only up to 3,000 realizations. And it varies between 2.48 ten to the minus two milirems per year and 3.24 ten to the minus two.

So, essentially, we don't see nice and smooth conversions. And we did some investigation to find out what might be the reason for that. It turned out that when we plugged the peak dose as a function of the number of sampling realizations, there are some extreme values. That is what is causing this kind of change in the peak expected dose value. And we have noticed that this kind of realization shows up in about one to 2,000 realizations. And this is something we are continuing to investigate further.

Next, we will start with sensitivity analysis. I will be talking about the distributional sensitivity analysis and subsystem value components in sensitivity analysis. And after me, Dr. Codell with start with the parametrics sensitivity analysis.

This distributional sensitivity analysis is done primarily to understand how the peak expected dose is going to be influenced if the distributional function assumption that we have received from various KTIs are not correct or at least to identify if there are some areas where staff need to focus more to determine if anything can be improved.

Two approaches we have followed. One is using a fixed range from here to here for changing the mean of the distribution by ten percent. So we have shifted the mean by ten percent. And in the second approach, we have completely changed the distribution function type. That means if in the nominal case we had a normal distribution, we changed that to a uniform distribution to see if that has a major impact. Similarly, if the distribution had a log uniform distribution, we changed that to log normal, because in log space we thought that would capture the difference.

Instead of working with all 330 parameters, we thought maybe changing for the top ten influential parameters that we have identified by using other methods would be more appropriate, because those parameters are already showing a lot of sensitivity. That's why in this talk we will

primarily focus on the top ten influential parameters.

And we have used two different sensitivity measures. One is the change to the peak expected dose, before and after changing the distribution function type and an effective distance between the CDFs. CDFs are constructed by using the peak dose from individual realizations.

CHAIRMAN HORNBERGER: Sitakanta, when you say you looked at the top ten percent in importance, how did you determine that, from a different sensitivity analysis?

MR. MOHANTY: Yes. Those were determined from parametric sensitivity analysis that Dick is going to talk about.

For the distributional sensitivity analysis, the two kinds that I saw, these two figures are showing their results. The ten percent shift to the mean with a fixed range, the results are shown here. And for the complete change to the distribution function, the results are shown by these blue curves -- bars.

Let me describe the results from the shift to the mean by ten percent. Clearly, it shows that when the distribution function type is increased, the mean is increased by ten percent, there is a 150

percent increase in the waste package flow multiplication -- a 150 percent increase in the peak expected dose because of a ten percent change for the waste package flow multiplication factor.

The second one that came out to be very important is the spent fuel dissolution, which is a pre-exponential term that defines that dissolution -- spent fuel dissolution rate. Fifty-seven percent change to the peak expected dose occurred because of a ten percent shift to the distribution function.

Similarly, when we changed the distribution function type we did not see that kind of effects for the two that showed up as important when the mean was shifted. Rather, the two that turned out to be important are the drip shield failure time and the neptunium retardation in alluvium. So, therefore, this clearly indicates that staff should revisit and determine if the input parameter distributions were not carefully looked at, at least the ones that are showing up as important in the sensitivity analysis should be looked at further, because these effects can be cumulative. So when we add these things up for many parameters, many sample parameters, that could influence the peak expected dose that we compute from the nominal case.

Next we'll talk about the subsystem of barrier component sensitivity analysis. This analysis is just an extension of the sensitivity analysis we are doing, first, to the parametric sensitivity analysis, distributional sensitivity analysis, then the system can be broken down in many different ways. One can break the system along the line of subprocesses, but here we have broken it down along the line of physical components, and we are primarily interested in seeing how much sensitivity we are getting from individual components. But then breaking down these components are very subjective, because one can have more components than what we have shown here. But it appears to be adequate for our purpose.

But it is very important to highlight here that this analysis should not be mixed with multiple barrier analysis. This is not a proposal to do analysis this way. Therefore, it should be clearly noted that this analysis is not required by -- there is no regulatory requirement for this kind of analysis.

And I would like to draw your attention to the representation of the repository in this column. The repository can be viewed at the top as an unsaturated zone. Then next to that we have -- below

that we have the drip shield. Below that we have the waste package, then waste form, invert, unsaturated zone and the saturated zone. So here you are seeing barrier components, but in the results that I will present in the next two slides, we show only six because unsaturated zone above the repository and below the repository will be treated as one entity.

And we will also show results from the one-on analysis, one-off analysis and cumulative addition analysis, because they all provide different insights into the system.

CHAIRMAN HORNBERGER: Sitakanta, I don't think I full understood something. You said that this was not intended to be an analysis of barriers, but then I've lost track of why you're doing this.

MR. MOHANTY: We are doing this purely to supplement the sensitivity analysis. We are trying to group them together. It's one way of looking at a group of parameters, so we thought maybe grouping the parameters along the line of a physical entity makes it easier to understand.

My purpose in showing that column in the previous slide was that these should be viewed as individual cases. Each column here represents one case. The group on the left represents the one-off

analysis; the group on the right represents one-on analysis. And the first column under the one-off analysis represents the nominal case. And the row at the bottom these represent the percentage change.

I would like to draw your attention to these numbers in the sense that the numbers on the left-hand side these are changes with respect to the nominal case results. The numbers on the right-hand side, these are with respect to the case where all barriers are suppressed, and the suppression of a barrier is represented by the gray color. That means if we go to the second column here, this shows the drip shield as a barrier has been suppressed. Under the third column, the waste package as a barrier has been suppressed. So, therefore, this number -- when the drip shield barrier is suppressed, the number at the bottom shows that the peak expected dose changed only by a factor of 34 percent. When the waste package value was suppressed, the peak expected dose changed by 62,200 percent. So likewise, these numbers represent changes with respect to the nominal case result. But these are in percentages.

CHAIRMAN HORNBERGER: And can you enlighten me just a little bit by what you mean by suppressed?

MR. MOHANTY: By suppression, we mean that the function of the -- okay, from a purely technical point of view here, the drip shield fails at a certain time; it has a distribution. By suppression here we imply that drip shield failure has been shifted back to time zero. That means drip shield may have failed at time zero, but if there is no infiltration because of the thermal hydrology until 10,000 years, no water is going to contact the waste package.

CHAIRMAN HORNBERGER: So the drip shield -- the suppression of the drip shield is equivalent to assuming that there is no drip shield.

MR. MOHANTY: Right, right.

CHAIRMAN HORNBERGER: Okay. Now, if we go to the waste package, that's a little more difficult for me. Does that mean that there is no waste package?

MR. MOHANTY: Right. Here, what it -- let me give you the detail here, if I can find my cursor here. When the waste package is gone as a barrier, what it implies is that the waste package has two functions: when the waste package fails, and the second is it contains -- it does not allow water to enter into the waste package through flow multiplication factor. Only a fraction of the waste

package surface area will contribute to the water getting into the waste package. Therefore, it will come into contact to the spent fuel. So when the waste package is gone, when the waste package is removed as a barrier, that implies that the waste package is failing at time zero. And, also --

MEMBER GARRICK: Does that also affect the composition of the water?

MR. MOHANTY: No. So that is an important point we want to make, that when we are doing this analysis we are not changing the physical processes that are going on.

MEMBER GARRICK: So you're really not accounting for the interactive effects.

MR. MOHANTY: Right, because your purpose is primarily the sensitivity --

MEMBER GARRICK: So this is not so much an attempt to see the physical event and the progression, as it is to deal with this question of sensitivity and uncertainty.

MR. MOHANTY: Right. Yes.

MEMBER GARRICK: Okay.

MR. MOHANTY: But I think it is also important to point out here that this removal, this one-off analysis, especially when it comes to waste

package, only affects the waste package that are already seeing water. So two things are happening: It is seeing water early and the second, more water is getting into the waste package. But there are lots of waste packages that do not see that water, as long as the unsaturated zone barrier is above -- unsaturated zone is above the repository horizon.

So, similarly, the numbers on the right maybe they should be viewed as a decrease, so there should be negative numbers. So here it means that when the drip shield -- when all barriers are suppressed and drip shield is added as a barrier, just the only barrier, and the spent fuel would be in the waste package somewhere here, but now we have no waste package, in that case the drip shield has a performance of about 63 percent. So this allows us to see how much performance individual are coming from these individual barrier components.

So here is shows that when the waste package barrier is added to a case where all barriers are suppressed, we have a 99.9 percent reduction in peak expected dose. Whereas, when the unsaturated zone is added, we have a reduction of 96 percent, and when the saturated zone is added, when others are suppressed, it's about 94 percent.

So we have carried this analysis a little further, and we have added to the one-on analysis. Here we are adding those cumulatively. The first column here represents when all barriers are suppressed. In the second column, this shows that this is similar to the saturated column you saw on the previous page. But when we add unsaturated zone to the saturated zone, it says that the peak expected dose has been reduced by 99.2 percent. Of course there are several decimal places that I'm not showing.

When we add invert to the unsaturated zone and saturated zone, then that reduces to 99.6 percent. And by the time we reach the waste package, this is 99.99, but maybe the number will change in about seventh or eighth decimal place. So then when we add all the barriers, all the barrier components, then we regain the nominal case.

Then we grouped all these barrier components together to reflect the engineered barrier and the natural barrier. Clearly, as expected, as we observed from individual component sensitivity, clearly, when we group them together, it shows when we compare that with respect to the nominal case, there is a -- and when the engineered barrier is suppressed, then we see a substantial increase in the peak

expected dose, which is about 808,233 percent. And when the engineered barrier system is there, but the natural barrier is suppressed, it's about 58,233 percent.

I think that ends my presentation. Now Dr. Richard Codell will take over.

DR. CODELL: Please don't adjust your sets. We're experiencing technical difficulties here.

CHAIRMAN HORNBERGER: While we're waiting, I'll interject and try to ask Sitakanta a tough question. Having looked at all of that one-on and one-off analysis, I'm not sure what message I'm supposed to take from that.

MR. MOHANTY: We are continuing to conduct this analysis. These results are quite fresh. We are also trying to figure out how they are going to contribute to the risk significance. The main reason we did this kind of analysis is to see if any barrier component in suppressing is shadowing the effect of other barriers. So to determine how these individual barrier components are performing, we had to separate those out to individual ones.

For example, if we go to -- I think it should be Slide Number 13, the one-on analysis for the drip shield, we see that when all other barriers are

suppressed, the drip shield reduces dose by 63 percent. That number -- we have not devised any better method at this time to determine whether the effect of drip shield is 63 percent or something else. Simply by looking at one-off analysis we could not figure that out.

Also, another reason for doing this analysis is that if something is modeled, then we can capture that effect in the traditional sensitivity analysis. But if the model doesn't represent that, then sensitivity analysis cannot capture it, because it is not in the model. We do our best to capture everything possible in the model, but there are also uncertainty about the models themselves.

So there are two important aspects here. One is uncertainty in the model themselves, number one; and number two, is the shadowing effect of one barrier component over others. So, therefore, by adding it cumulatively, starting from the saturated zone and coming up all the way to the level of drip shield or the unsaturated zone above that, that gives us some insights. Simply from those numbers we can derive if there are any shadowing effects.

MEMBER GARRICK: I guess the thing that --

(Pause.)

DR. CODELL: Maybe I should, to save time, just work from the viewgraphs. Hopefully we'll be -- in a minute or two we'll have the presentation, and I'll be able to put it up on the screen.

I cover parametric sensitivity analysis. We're talking about the nominal -- we're on Slide 15. We're covering nominal scenario only. And the purpose is to determine sensitivity of parameters singly and also in groups. The grouping is something new this year. We're using -- there are two methods we're using for parametric sensitivity. The first is statistical methods that evaluate sensitivity to a previously calculated pool of vectors that were generated by the TPA 4.1 Code. In this case, we're using generally 4,000 vectors cover the range of the parameters. And then there are non-statistical techniques that get to a sensitivity a second way, which is to redirect the calculations to get the maximum -- extract the maximum sensitivities from the models.

We generally look at the peak of each realization and look at the sensitivity of that, even though the standard is based on something else; that is, the peak of the mean dose. Starting on the next slide, the statistical methods, these include

primarily regression on raw and transformed variables, non-parametric tests, like Kolmogorov-Smirnoff tests and assigned tests, the parameter tree approach, and there's some new work on cumulative distribution functions sensitivity method and some other work recently developed by Sitakanta Mohanti and Justin Wu at the Center.

Another method along these lines is a method which is based on the mean -- calculating the sensitivity of the mean dose directly with respect to the means of the independent parameters and also the variance of the independent parameters. These are too new to really go into any detail but they're developmental.

The non-statistical methods include differential analysis, Morris method and FAST method. These are things that we covered before. There's one new method that -- factorial design of experiments which has the unfortunate acronym DOE, it's usually called DOE.

(Laughter.)

This is something that John Telford, of the Office of Research, and I have been working on for several months with some pretty impressive results, I feel. I'll go into that in a little more detail.

Let me just take one second here to open up the correct file.

(Pause.)

Okay. So we're at the bottom of Slide 16 now, starting at 17. The next slide shows -- this is a tried and true method that we've been using for several years now. We call it a composite statistical method. This is to look at, in this case, six statistical tests of various kinds, looking at transformed and untransformed variables. And it's really a seat-of-the-pants kind of method but works quite well.

We used six statistical tests with 4,000 realizations. And then looking at each test and factor the number of times the variable in question is statistically significant in each test and its rank and then develop a single list of parameters, top parameters from the number of times they appear and the ranks of the six tests. And when you do that you come up with a list arbitrarily cut off at ten variables for 10,000 and 100,000 years, showing that a lot of the parameters that show up have to do with how much water gets in contact with the waste.

I'll show some comparisons of the methods later, but to get into the new work we've done, John

Telford and I, the factorial design of experiments. Basically, factorial design, in the simplest form, is to look at two values of each of the variables, a high and a low value. We took fifth and 95th percentile of each distribution, and since there were 330 variables, if you looked at all possible combinations, you'd have two to the 303 runs required, which at the present rate would take ten to the 94 years. And, of course, in maybe 1,000 years this will be --

MEMBER GARRICK: Are you looking for permanent employment?

(Laughter.)

DR. CODELL: In 1,000 years things might be much better, but right now it's out of the question. So the fractional factorial design is what you have to use, but it gives you reasonable time estimates, but it's somewhat ambiguous.

So the way we did it is looking at the sampling iteratively, that is running a fractional factorial and then using other information from the runs to refine the list and then repeating on the refined list several times until we're quite sure that we've gotten most of the important variables. And this took a lot of trial and error, but we think we hit on a good procedure for doing this.

The advantages of this technique is it's systematic and potentially precise. It's easily interpreted with a powerful, statistical techniques like analysis of variance and trees. And it does reveal interaction among variables instead of looking only at sensitivity of single variables. I think this is an important point. Disadvantages are it's still costly and difficult to implement. And looking at only the high and the low value, you're not looking at the range of entire variable.

So this is how we went through the procedure. For the 10,000 year case, first looked at a design set using some statistical software of 2,048 variables, and we identified 100 potentially sensitive variables. We reduced that list to 37 on the basis of other information. For example, even though some of these variables appeared to be sensitive like seismic parameters, you could see from other results that there weren't any failures, so you knew those variables were confounded and could be eliminated from consideration.

And the second screening -- that was the first screening -- the second identified ten variables and then we went into a full factorial with only ten variables, which is a reasonable number to deal with,

and identified six to eight sensitive variables. When you do this and you go through the analysis of variance, one of the byproducts is a tree diagram. And this shows very clearly that if you follow the path of the cursor here, a low value of drip shield failure time gives you -- and a high value of the flow multiplying factor, the diversion factor and the fuel dissolution factor and the waste package effective fraction leads to the highest dose.

So this kind of information is much more revealing than looking at sensitivity of single variables at a time. This same sort of information, incidentally, comes out of what we call the parameter tree method, which is a statistical technique, but this is much more precise, whereas there's a lot of uncertainty in the parameter tree approach.

The next slide shows the same sort of result for the 100,000-year run, and it also shows the high and the low value of each variable contributing to the highest dose.

Just to show that we think we've captured, with a very small number of variables, most of the uncertainty, the next few slides reconstruct some of the results of the original run with the 330 variables and the reduced set, both either from regression or

from fractional factorials. This is a cumulative distribution function of the peak doses showing that especially for the high end of the dose curve that we've captured most of the uncertainty just with ten variables from the regression analysis or eight variables from the factorial design method. The lower curve shows the mean dose for the same calculations, 330 versus ten for regression and eight for the factorial design. So even though it's not perfect, we've captured most of the uncertainty with a very few number of variables. And the same is true for the 100,000-year result.

Now, the next set of slides, moving away from the factorial design now, there were two options for looking at sensitivities. The first one is that we have -- we can look at the peak of each individual run and look at the sensitivity based on the number or we could look at the time of the occurrence of the peak of the mean and look at that. The upper graph shows the sensitivity result looking at the mean dose; the bottom is looking at the peak of the individual doses. Except for the first two columns here, the results are quite different, and we're tempted to say that the sensitivity measure and statistical parlance has more power using the peak dose from each

individual run rather than the mean.

But there's one interesting factor here. If you look at this particular variable, drip shield failure time came out about number 20 on this measure using the mean of the peak dose, and yet it came out quite high looking at the individual peak doses. This is not an error. This is -- there's a real reason for this that isn't obvious, and the next couple of slides really get to this -- why does drip shield failure time differ?

MEMBER GARRICK: Dick, could you say something about the sensitivity measure, what it really is?

DR. CODELL: Well, I'll let Sitakanta address that. He prepared these slides.

MR. MOHANTY: For the sensitivity analysis, we need a point value. That means we have dose as a function of time, but when we do the analysis it has to be a point value that represents for the 10,000 years. So it's a matter of whether we should choose the peak from that realization or should we choose the value, dose value corresponding to the peak expected dose? That will be the point value.

So in other words, the red bars, those are showing the sensitivity analysis using the dose values

corresponding to the time when the peak expected dose occurred. Whereas the figure at the bottom that is indicating that peak can occur any time in 10,000 years so that it is independent of the time of occurrence. So, therefore, it reflects sort of the whole time domain, whereas the one at the top represents a particular time.

CHAIRMAN HORNBERGER: But what are the units on that sensitivity measure?

MR. MOHANTY: Oh. We have different sensitivity measures from different methods. This particular one is representing one method that we have used for the two graphs. So that measure is essentially, but it's kind of hard to explain. This is extracted from the Morris method in which we take the sensitivity from individual points and average that, and we determined the mean of the del Y over del X where X is the variable that is being changed. Del Y is the dose value that is being changed. So this is an ensemble statistics so that sensitivity measure is based on the ensemble statistics, both mean and variance.

MEMBER GARRICK: But it is in a change in dose per unit change in parameter.

MR. MOHANTY: In the parameter, right.

DR. CODELL: Okay. Thanks, Sitakanta.

CHAIRMAN HORNBERGER: But you must normalize somehow.

MR. MOHANTY: Yes. The parameters are normalized.

CHAIRMAN HORNBERGER: Okay.

DR. CODELL: On the next slide, I wanted to talk about the treatment of data variability and performance assessment modeling. This particular piece of work came up during the SAS review of the TSPASR and the SSPA, and it was called the galsean variance partitioning. It was basically how you treat data in the model.

It isn't exactly how DOE is doing it, but it leads us to some interesting conclusion on how we should deal with experimental data uncertainty either because of lack of knowledge or variability. And the difference between these two kinds of uncertainty, epistemic and aleatory, is often blurred, for example, treatment of corrosion rate data for the waste packages and its effects on dose.

To get at this phenomenon, we put together a model based very loosely on NRC's model and DOE's model, but it's a separate model. NRC's TPA model we represent variability and waste package corrosion by

a few representative waste packages -- only one per subarea, ten in all. Whereas DOE has in its Total System Performance Assessment uses the patch failure model that allows significant spatial variability of failures.

We could look at the data on corrosion, and we could say it's either -- this is real data from the corrosion experiments on the coupons and say it's either a fixed but uncertain rate or a spatially varying rate due to the material and environmental variability.

On the next slide, I showed this very simple model that deals only with a few parts of the model, particularly the waste package corrosion and the dissolution of waste in a fixed number of years once the waste package has failed. Now, there are three possible models. Model 1 is the whole repository. That's where you take this corrosion rate data, shown here as a density function, and you apply it to each and every waste package identically; that is, they'll all fail at exactly the same rate, pretty much, there is some slight variation, but at the same time. Whereas the other extreme is Model 3 where each patch of each waste package is sampled from the distribution so that each and every waste package and

each and every patch has a different failure time. And Model 2 is in between those two extremes.

Now, if you take this model and you just look at, for the present time, five realizations, as shown in this figure, you'd see that Model 1, where every waste package fails at about the same time, gives you five individual peaks, and they're all rather high, because when they fail at the same time you get a big release and therefore a big dose. Whereas Model 3, where you have this patch failure, they're all pretty much the same and smaller.

The interesting thing is that I wanted to point out here is that the dose and the way the NRC has defined in the rule as the peak of the mean is very sensitive to the timing of the peaks, so that even though these individual peaks are high, when you look at the way that Model 3 always fails the same, each new realization looks pretty much like the last one, these all line up. So when you take the peak of the mean dose, Model 3 actually gives you a higher dose, which I will show.

And how does that relate to a few slides before where I showed the drip shield failure time being an important parameter? Well, drip shield failure time determines the timing of the dose. If it

fails early, then the release is early. If it fails late, the release is late. That's the same effect as changing Model 1 to Model 3. And that's why it showed up in one way when you look at the peak of the mean dose and another way when you looked at the peak to the individual doses. But that was an interesting conclusion.

MEMBER GARRICK: Again, that's dependent upon the corrosion model that you --

DR. CODELL: Well, yes. And the way we've treated drip shield failure time in the TPA model is just a sample failure time. It just relates -- it's just a -- it could have been another example of the same phenomenon.

MEMBER GARRICK: Right. And the other thing here is that there's going to much greater variability in the setting than in the waste packages. So whatever you take advantage of with respect to the similarity of the waste packages could be very offset by the variability because of spatial considerations.

DR. CODELL: It could be but we don't have enough information from the corrosion rate data to know which is which, and that's a dilemma. A very important factor in our analysis is how quickly the waste packages will corrode. And even though it seems

to be a very long time, if it were not a long time, then we'd want to know whether the variability in the data was due to real spatial differences or experimental -- or other unquantifiable errors.

MEMBER GARRICK: And, of course, in the DOE model, they'd decouple the drip shield contribution from the diffusive transport out of the waste package.

DR. CODELL: Yes.

MEMBER GARRICK: So it really depends upon how you structure the thing. I'm curious about how you screened your parameters.

DR. CODELL: I'm sorry, which slide were we?

MEMBER GARRICK: Well, when you go from 900 to 330, to 100, to 37.

DR. CODELL: Well, actually, the 990 were screened by experience. We've, at various times in the past, looked at all those variables varying and decided that most of them didn't contribute anything to the results. So those were held at fixed values. The screening that took place in the factorial design was more systematic, because we started with 330 and worked our way down. And it was either based on the sensitivities we observed in the analysis or variance

or --

One of the problems with fractional factorial design is a problem called confounding, and that's where a variable can be mistaken -- sensitivity in a variable can look like it's sensitive but it's actually a combination of several other variables. And it's just a numerical combinatorial problem, not a real physical problem. But by looking at the physical outputs of the code, for example, seeing that the factors that looked sensitive, that had to do with seismicity, couldn't have been because there weren't any failures due to seismicity. So we could eliminate those. So it took a little bit of a combination of the silicon and the carbon computers to reach this conclusion.

MEMBER GARRICK: Did you call this the confounding phenomenon?

DR. CODELL: Yes.

MEMBER GARRICK: That's a good name.

DR. CODELL: It's not my -- that's what it's called in the factorial design method.

CHAIRMAN HORNBERGER: How are you sure at the end of the day that you don't have some aliasing left in your final ten or whatever --

DR. CODELL: Well, there can't be any when

you do the full factorial.

CHAIRMAN HORNBERGER: Oh, right.

DR. CODELL: That's the --

CHAIRMAN HORNBERGER: So once you choose the ten it's okay.

DR. CODELL: Right. Yes. And the final test was seeing how well you did by comparing it to the original.

Well, getting back to this little experiment on the two kinds of uncertainty, the epistemic and aleatory, the first result shows for a full set of realizations that the peak of the mean dose the Model 3, where you have the patch failure, gives you the highest result. This may seem counterintuitive, but as it turns out, if you're sampling each and every patch, you end up getting the similar kinds of failures each new realization. And that's why they look identical and fall on top of each other, leading to a high peak of the mean dose. And the other models give you much lower doses.

However, this is sensitive to other parameters in the model, and what we determined when all was said and done was that if you look at a much slower release, say 100 times slower than what we used in this example, all three models pretty much fall on

top of each other. And when looking at the ranges of parameters in the Department of Energy model, probably it is more like the case on the right more than the left. But it's still an interesting phenomenon and explains some other interesting features like the drip shield failure time result we got.

Something related to this previous exploitation is risk dilution. This is something we worry about. It's not good enough just to increase the range of distribution if you don't know it. There's some cases if you do that, you'll end with actually a lower dose, which isn't what you wanted at all. And here's an example. Once again, drip shield failure time. If you have a narrow range, this green curve, or a wide range, the blue curve, you'll get different results. And the narrow range gives you a higher dose than the wide range. Once again, this is one of the parameters that has to do with the timing of the doses, and when you increase the range of that, you're going to end up with a lower result.

So summing this all up --

CHAIRMAN HORNBERGER: Dick, let me -- I don't know, I think I'd like to challenge you on that one, because you said you put in a wide range and you may get a lower dose, and that isn't what you want.

If in fact you have a broad uncertainty range, why isn't it what I would want?

DR. CODELL: Well, I think the --

CHAIRMAN HORNBERGER: I mean if you really -- if your uncertainty and failure times for drip shield really is -- I mean I suppose it ties back into your aleatory versus epistemic, because if you really believed that every single drip shield was going to fail on day 372, then it really matters. Is that what you're saying?

DR. CODELL: That's right. That's right. Yes. And this is interesting because I think prior to NRC's regulations for high-level waste, I think most people considered looking at the peak of the individual doses as a factor. And automatically if you put a wider distribution in, you're going to get a higher -- one of those is going to be a higher peak. But it doesn't work that way when you look at the peak of the mean curve; it's just the opposite.

CHAIRMAN HORNBERGER: Which I assume is why even though the regulation calls for the peak of the mean dose, you will require the potential licensee to display all sorts of things, including all of the uncertainty?

DR. CODELL: Well, I wouldn't go too far

there. I think I'd be stepping out of bounds. I don't think we would require anything like that. If Tim is in the audience, he could probably rescue me right now.

CHAIRMAN HORNBERGER: Maybe I could frame it another way. The ACNW will want to see that.

DR. CODELL: Yes.

MR. McCARTEN: Well, as Dick's slide indicates, I mean the key there is the inappropriate use of a wider distribution. We are clearly interested in the distribution. And if the uncertainty is there, we're not saying don't include the uncertainty you have.

If there are some arbitrary decisions that are done and sometimes done in the sense of conservatism, let me make this bigger, I'm uncertain about it, we want to look at that to make sure, well, you may think it's conservative to make it bigger but you've actually, in essence, produced a lower dose. And so you want to have an appropriate range. As Dick indicated, I think we are going to look at all the information the Department gives us.

MEMBER GARRICK: Let me understand something. Is this distribution a random variable?

DR. CODELL: Yes.

MEMBER GARRICK: Because what we're really interested in is our uncertainty about a fixed variable.

DR. CODELL: Well, it actually is an uncertainty about a fixed variable in almost every case. I think in every case in the TPA Code it's uncertainty about a fixed variable. I would consider that a definition.

MEMBER GARRICK: And if that's the case, then of course you know want to be very careful about manipulating a broad distribution into -- or a peak distribution into a broad distribution as to what information you might be losing in that process.

DR. CODELL: Right. Well, these density functions that we use are based on either data or people's idea of what the data should look like. And it isn't always -- they aren't always precise.

MEMBER GARRICK: Well, as George says, we're going to be very interested in following this.

DR. CODELL: Preliminary insights from the sensitivity analyses for 10,000 years, factors that control water/fuel contact seem to be the most important and most doses from low retardation, long half-life radionuclides, like technetium. For 100,000 years, it's interesting that waste packages usually

fail by 100,000 years, so the parameters aren't always showing up as being conservative, because you'll usually have failure anyway. Changing them isn't going to make any difference.

The fuel/water contact is still important, and the dominant radionuclide, neptunium-237, seems to be very important, so parameters associated with that are important. For barrier sensitivity, the preliminary results that both natural barrier and engineering barrier make substantial contributions.

This is some additional work in progress that was too callow to talk about today, but we've acquired some neural network software, which seems to be very powerful, and this is basically doing non-linear regression. We've had some limited success with it so far.

Dave Esch and I took some training in it, and I think you'll probably see this next we make a presentation. We're looking at new sensitivity measures consistent with the peak expected dose, as we showed in the previous slide, and looking for efficient distributional sensitivity methods like the cumulative distribution function sensitivity that allows us to look at the sensitivity at different parts of the cumulative distribution; that is, high

dose and medium dose or low dose and also the means -- the sensitivity of the mean dose directly.

Some other work, we're trying to get a handle on barrier performance in a couple ways. We're trying to define what a degraded state of a barrier means. This is a very difficult problem trying to figure out how to define a barrier as failed, like what does a failed waste package mean.

Just looking at the kinds of barrier sensitivity analysis that Sitakanta presented earlier, there are six barriers, so two to the six is 64 possible combinations of failures, from everything failed to everything working. There has been 29 of the 64 analyses completed, and we've made some preliminary shot at making a tree structure, but it's possible to draw a tree with this result but looking more powerfully at -- looking at it with more powerful methods like analysis of variance there's not enough runs yet to do that, but we're hoping to do that in a future presentation.

In conclusion, parametric sensitivities provide useful risk insights. The method we've been using, the sensitivity method where we're combining ranks of the various statistical methods still works very well.

Factorial design shows great promise and clearly defining the sensitivities and the interactions of the variables. The distributional sensitivity technique that Sitakanta presented is an effective approach identifying the impact of the choice of parameter distribution and the shape and the shift in the mean. We've shown that inappropriate parameter ranges can lead to risk dilution in some cases, and the treatment of uncertainty as lack of knowledge, epistemic or variability, can affect the peak risk calculation. That's the end of our presentation. We'd be happy to take additional questions.

CHAIRMAN HORNBERGER: Actually, before -- now that John is back. I started before you got back from lunch, John, but this is really your bailiwick, so why don't you run it.

MEMBER GARRICK: All right, well, let's see if there's some questions. Of course, I have a few.

Milt?

MEMBER LEVENSON: One comment.

MEMBER GARRICK: Microphone.

MEMBER LEVENSON: One comment and then one question based entirely on ignorance. One of the

things is that I guess I sort of disagree with your use of terminology because no matter what you do in the way of assumptions, you are not going to change the risk. So you can't dilute the risk or increase the risk. You may change your calculated number, but it's not really the risk.

But on Slide 13, I'm having trouble relating this to the physical world in that on the one-OFF, if you remove the waste package, you have a 62,200 percent change.

MEMBER GARRICK: Can we see that on the screen? Can you put the projector back on, please?

On the one-OFF analysis, when you remove the waste package, you have a 62,200 percent change, but with the one-ON analysis, none of the other barriers are there. You just add the waste package. You only have 100 percent change. Factor 2. It doesn't seem consistent with the physical world, as I visualize it.

MR. MOHANTY: Let me explain the difference. Under the one-OFF analysis, the first column represents the nominal case. For the nominal case, the peak expected dose is .021 millirems per year, whereas under the one-ON analysis, we are determining the percent in change based on the first

column under one-ON analysis. And that number, I don't remember what that value is, but we are using that number to determine the change. So that means at most it can be that. So when we put the waste package, so 99.9 percent represents a reduction in what we observe under column 1.

CHAIRMAN HORNBERGER: You can't take away any more than 100 percent. But if you have something to start with, you can change it by 62,000 percent.

MEMBER LEVENSON: I guess without the numbers, it's very difficult to determine what the significance of what this chart is.

CHAIRMAN HORNBERGER: Even with the numbers, I would maintain it's very difficult to figure out what the significance of what this charge is.

(Laughter.)

I don't mean to be too severely because I know we are interested, like you are in barrier performance. But it strikes me, Dick just casually said it's a really difficult problem to figure out what it means to have a barrier suppressed. And I agree with that. It just doesn't make sense to me to even consider changes as if all the drip shields failed at Time Zero. I don't understand what you're

doing.

MEMBER LEVENSON: It's not so much to understand what you're doing. It isn't clear to me what the significance is.

CHAIRMAN HORNBERGER: Right.

MR. HAMDAN: One of the main objectives of this is one that sensitivity analysis is one that is not risk, but in response to your question and that is to test one other. And one could argue that these barriers individually or in combination is to see if one is working and this has not been in all these slides clearly that you can elicit in slide 3, clearly the emphasis also I think he did answer and answer very well. But the question as to what added value the sensitivity adds to the model and whether the model has been improved has not been addressed.

MEMBER GARRICK: Yes, but the black box here is the degree to which the model represents reality and I think that's part of what Milt is struggling with.

You know, it's this question of if you tried to look at this as a system and you apply the basic equations of continuity and conservation of mass and momentum, etcetera, etcetera and you flow through the system, this model isn't doing that because the

800-pound gorilla here is the water and the chemistry of the water. And the chemistry of the water is extremely sensitive to each of the stages it passes through.

So we're not talking about something that's so much represents reality as we are talking about some very interesting concepts that you can apply in a Monte Carlo-type analysis, but at least that's my perspective.

Ray?

VICE CHAIR WYMER: I'll be a little bit facetious. I certainly admire the sophistication and complexity of these analytical tools and the variety that were used in these analyses and that's impressive, but I couldn't lay a finger on it myself. But I was pleased to see that in your preliminary sensitivity analysis that you confirmed what I thought for the last two or three years that --

CHAIRMAN HORNBERGER: Chemistry is important.

VICE CHAIR WYMER: Natural version as a substantial contribution, that looks pretty good.

(Laughter.)

Waste packages fail corrosion parameter is not sensitive. Fuel water contact, that's important,

pretty good.

And retardation of neptunium seems to me like that's important. But I thought I knew that stuff.

Factors controlling water fuel contact dominate performance. That's right. And most dose from low retardation and long half-life radionuclide, sure, I know that trivializes the degree to which you understand these things and the sophistications, but nonetheless the answers are sort of self-evident for whatever that's worth.

MEMBER GARRICK: George?

CHAIRMAN HORNBERGER: I just wanted to make a final comment on the barrier component sensitivity. I really do understand what Latif said and that is that you do a lot of these things to try to understand what's going on with your modeling. I certainly have no problems with this.

The issue that I have, the difficulty I have with slides like this is that there's too much chance for mischief making with the numbers by people who will want to use them for purposes that are not to understand how your model is working. And I guess I"d just ask you to give a little thought to that as you present these things.

MR. CODALL: We've given a great deal of thought to that. In fact, at every level of review, we've been asked to be sensitive to this and to put disclaimers in that this not underlying not required by the regulations.

I think people who want to make mischief of this will do so regardless.

But this is the kind of analysis that's often done for safety. You look at the failure of a system. You look at what happens when an engine on an airplane dies. It's nothing not wrong with it, in my opinion. It's just my opinion.

MEMBER LEVENSON: I think there's a significant difference in fact, that's one of the points I think George made earlier that an engine is either on or off and you can -- this is a legitimate analysis for that sort of thing. The waste container is not either in existence or not in existence, and therefore, I think you have to be very careful about using what is a legitimate analysis under other conditions or this one that might be much more legitimate to say what happens if 10 percent of the waste packages fail early, etcetera, rather than -- they're either on or off.

MEMBER GARRICK: Yeah. I think that

there's no question that the modeling test exercise that you've done here is very interesting and very powerful. As I was saying earlier thought, I think that what we're really interested in is information that would give us confidence that the models that are being employed are doing a reasonable job of representing reality in terms of what's happening.

Now maybe this can contribute to that, but what is really something that concerns us is the interactive effects of these different barriers and how the one thing that would suppress some of the mischief that we talk about would be to do this same exercise for different models.

Take for example, the TPA model and do the exercise, and then take the diffusive transport model of DOE and do the exercise and you would certainly see that things would line up differently. And it would clearly indicate that how model sensitive it is.

But again, I guess the question I would ask is what contribution comes from this work towards creating a model that we have increased confidence in in terms of representing the performance of the repository?

MR. MOHANTY: Let me start with one-ON analysis. What that figure tells us is that on

saturated zone, unsaturated zone is making quite a bit of contribution and these individual contributions perhaps could not have bene seen if we did not isolate those from other either components or in a broad sense subsystems.

So that tells us something. And also when we compare that say with an invert, we are seeing only 2 percent change. Then we are going back to the total system for performance assessment code to determine why we are only getting .2 percent and we did go back and find that the way in what is modeled in what is supposed to reduce flow or delay transport, but it just so happens that the flow through invert is predominantly fracture flow.

So when the flow is a predominantly fracture, in the fractures and we are not assigning any retardation fractures to the fractures, therefore, the invert is almost completely bypassed in the TPA approach. So that is a kind of insight we gain when we do this kind of one-OFF one-ON analysis or cumulative analysis.

VICE CHAIR WYMER: I would have liked to have seen that sort of thing in your table of preliminary insights, the two cases you just cited are much more informative.

MR. MOHANTY: If I can make another point that there are two ways we can determine all components for how well the components of the code is functioning. To give you an example, if the packages were going to fail at 1 million years, then the only way we can find out that what is what is affecting the packages is we go with continual calculus for 1 million years, are we deliberately suppressed that to find out what the impacts are if we are to fail early.

So by doing this kind of analysis that prevents us from going to much further into the future to million years because we can gain similar kind of insights by deliberately doing the sensitivity analysis by suppressing components.

CHAIRMAN HORNBERGER: I have a question now that you have mentioned your one-ON analysis. If we look at that lefthand column, okay, you have a dose associated with that, is that right? What you said was that we could read those as 99.9 percent reduction in dose?

MR. MOHANTY: Right.

CHAIRMAN HORNBERGER: So my question is what is the dose in that lefthand columna nd how did yo calculate it?

MR. MOHANTY: Under the one-OFF analysis

or one-ON analysis?

CHAIRMAN HORNBERGER: One-ON analysis.

MR. MOHANTY: On the one-ON analysis, this is not a real dose where barriers are suppressed. We do honor the various processes in the TPA code. We do not veer away from the processes too far because we know that we are limited simply by this is just a technique we are using.

CHAIRMAN HORNBERGER: All right, so then if I go to the first column, the drip shield, the 63 percent reduction in what?

MR. MOHANTY: We do have a dose value.

CHAIRMAN HORNBERGER: How did you calculate it?

MR. MOHANTY: This is by suppressing all components.

CHAIRMAN HORNBERGER: Okay, which means what did you do, dissolve all the fuel instantaneously in the --

MR. MOHANTY: Yes.

CHAIRMAN HORNBERGER: And so it's a high dose.

MR. MOHANTY: It is a high dose, yes.

CHAIRMAN HORNBERGER: I mean that's a high calculated dose. I don't want to get in trouble with

--

(Laughter.)

So I just point out that again, even on this one we're saying oh yes, the natural, the insight that you gain, it's quite artificial and I'm much more comfortable with Latif's interpretation that what we're doing is learning how the components of the model are working.

MEMBER GARRICK: Also, those kind of reductions in the kind of doses we're talking about are not very relevant.

I don't know that that really tells us a great deal about the protection provided by those components. I'll have to think about that, a good deal more. And I still worry about the fact that there is interaction between the barriers and what the waste package sees in terms of input material is different than what the invert sees as different what the unsaturated zone sees and so on.

And that could be a major factor in what really happens. All the peer reviews of the TSPAs have given great attention to the importance of water composition because that's the mechanism by which everything happens and that's just the process of applying principles of continuity from the

infiltration model, if you wish, namely the geology above the waste package through to the waste package and so on.

So again, there's no question this is an intriguing process and it does, as Latif says, but we're going to have to be a lot more diligent students and studiers of this before we can really see what it contributes to reality.

MR. CODALL: In terms of projected work, we are getting together soon to talk about what degradation of barriers means. I hope in the next few weeks, Tim McCarten is convening a group to better define in terms of what is expected in the regulations what barrier degradation means.

This one-OFF, one-ON analysis probability overkill.

CHAIRMAN HORNBERGER: yes.

MR. CODALL: But getting at the -- getting a finer level is the next step. This maybe you consider this a first step and gaining information about importance of barriers.

MEMBER GARRICK: Go ahead, Latif.

MR. HAMDAN: But do we need a more refined -- it seems to me that from this beautiful presentation the staff has already has all the tools

it needs what it needs to do from the subject. After all, the barrier requirements which was about 60 has been removed by 63. This morning Commissioner McGaffigan complained about things could grow and grow and grow.

Now with the two that you have here, it seems that either you are doing a very nice job with what you have, so why bother with to come up with new tools that you want to try and new analysis, specifically tools to do the same thing again and again.

I would suggest that you rethink this because this is really maybe you can do what you want to do with what you already have and keep in mind again that the barrier capability performance for individual barriers which was about 60 is now omitted.

MR. McCARTEN: I guess -- we hear what the Committee is saying and there's no question we've had a lot of discussions internally and that's the reason. It's clearly stated. These types of analyses are not required to demonstrate compliance with the barrier requirements in 63. But what we're trying to do and for the Committee I think Dick and Sitakanta both tried to give all the things we're looking at with potential to increase our understanding, and I think

the concept of all these things, we're just throwing out where we're going.

There is a huge downside to doing barrier neutralization because people jump to those numbers at the bottom and the value is not in those numbers at the bottom. And what we're -- I like to think that when this is done, it's a way to probe and test your own thinking of how the code is working, how you think the system is working and this is just another way to poke at you, your brain a little harder, to think a little more.

Ultimately, what you're not seeing and we're not there yet is what kind of information about the system can you pull out and that's the key. And I think this is a way to kind of jiggle the system a little more.

Maybe it's not the right way to go, but I think it's a way to push your understanding and I think that's the key we need to get to as you guys are indicating. And we're not there yet. We owe you something more. Where's the understanding in this? And right now, it clearly is not at those bottom numbers. It's deeper than that.

MEMBER LEVENSON: Let me ask a question sort of in that relationship. In the one-ON analysis,

the unsaturated zone and the saturated zone have for all practical purposes the same significance, whatever that is. But in the one-OFF analysis the significance is different by more than an order of magnitude. What do we learn from that?

MR. McCARTEN: Well, these numbers in order of magnitude, I don't think is necessarily that significant, but the next step is what -- the key is understanding the capability of the barriers and what's going on and why those numbers came out. I think that's what -- you may use this analysis to push you a little harder about the understanding of the capabilities of the barriers, so you clear -- oh yeah, that's why those numbers came out that way, but that's sort of the next step with this and whether this is the right way to go or there's other approaches re better or there's as Dick indicated some intermediate steps or this is the first step, that's where we're at now and we're just trying to as a group, we're always trying to do additional analyses to see if it's helpful.

CHAIRMAN HORNBERGER: Tim, you remind me of one of my favorite quotes, the purpose of computing is insight, not numbers. The purpose of computing numbers is not yet in sight.

(Laughter.)

I do have a question for Dick, actually. I was really intrigued because I hadn't thought of that before, but DOE's patch model really does lead them to get essentially the same failure rates on every realization.

Do you see this as a problem in DOE's code?

MR. CODALL: No. I think it's probably somewhat more realistic than what we chose, so that's a point for DOE's conservatism.

CHAIRMAN HORNBERGER: But it strikes me that -- I mean, that's equivalent, I think to your saying that all of the uncertainty is aleatory. I hate those terms, but environmental variation and it strikes me that they're probably -- potentially could be another component if for no other reason that you would have differences in fabrication of casks.

MR. CODALL: Right, but the problem is that the data don't tell you which is which. And then I think though that the answer that -- is that it doesn't -- it seems that for the ranges of parameters that we're dealing with, the results aren't too different no matter what you assume and that's somewhat reassuring.

CHAIRMAN HORNBERGER: Actually, I had -- I've often somewhat facetiously suggested that DOE could build a better safety case by purposefully damaging canisters in a certain pre-determined rate so that they all wouldn't fail at the same time.

(Laughter.)

MEMBER GARRICK: This reminds of the old days of reliability analysis when they had no failures, someone would assume a failure, a horrible, horrible thing to do.

Well, this is very interesting and we'd like to continue. I think that my perspective on this that what you're doing needs to contribute to a couple of things or we would have to challenge it.

It's wherewithal. One, a better understanding of the contribution of the individual barriers. And two, a greater confidence that we can build a model that represents reality a little more effectively after doing this work than we could before. And if it doesn't do -- contribute to those things, then I would have to wonder.

MR. CODALL: Well, I'd just like to point out this is not part of this presentation, but we're starting development on TPA 5.0 and we're putting back in that code, the diffusion model. It was taken out

earlier. I think I was probably responsible for putting it in and taking it out because it didn't seem to make any difference, but since DOE is depending on that release pathway, we're putting that back in too, so we'll have a handle on it. So there are changes to the code that will improve it.

MEMBER GARRICK: I sure wish you'd put something in there that would account for the chemical effects inside the waste package.

MR. CODALL: There may be something like that going in. Are you aware of something, Sam?

Nothing comes to mind. But where people are chemists here and at the center who worry about such things.

MEMBER GARRICK: That's where the action is relative to the mobilization of the waste and the creation of the source term and I think a lot of attention on that would pay high dividends.

All right, well, we're running a little behind. We thank you very much.

MR. CODALL: Thank you.

MEMBER GARRICK: And I think we'll adjourn for a recess.

(Off the record.)

CERTIFICATE

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

Name of Proceeding: ACRS 133rd Meeting

Docket Number: (Not Applicable)

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.

Matthew Needham
Official Reporter
Neal R. Gross & Co., Inc.

Sensitivity and Uncertainty in the NRC Total-system Performance Assessment Version 4.1 Code

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CNWRA
A center of excellence in earth sciences and engineering

Briefing to ACNW Members
Rockville, Maryland
March 20, 2002

Outline

- Purpose of Analyses
- Overview of Total-system Performance Assessment Preliminary Results
- Sensitivity Analysis Results
- Effects of Treatment of Data (Variance and Uncertainty)
- Preliminary Risk Insights

Purpose of Analyses

- Gain Risk Insights and Risk-Inform the Program
- Understand the System as a Whole
- Understand the Factors Important to Performance
- Improve Capabilities to Review Potential License Application
  - —DOE performance assessment results (e.g., potential risk dilution)
  - —Sensitivity and uncertainty analyses approach

Background

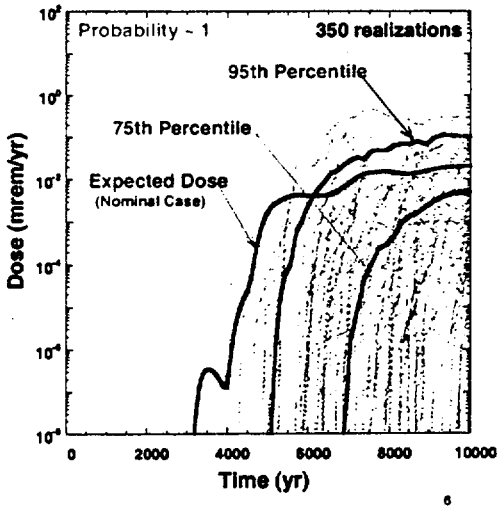
- Total-system Performance Assessment 4.1 Code Uses DOE EDA II Design
- No Analysis of DOE Low Temperature Operating Mode Concept
- Total-system Performance Assessment Code Has More Than 950 Parameters; 330 Sampled
- Alternative Conceptual Models Treated on a Case-by-Case Basis (i.e.,alternative models not sampled)
- Notes:
  - —Analyses performed mainly for developing staff understanding; they are not mandated by regulation
  - —Results are preliminary; input received from other key technical issues could change results

Performance Assessment Results

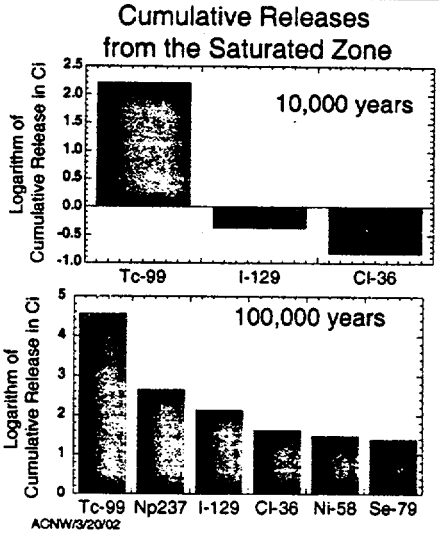
- Performance Measure: Peak Expected Dose to the Reasonably Maximally Exposed Individual
- Results Shown for Two Scenario Classes
  - —Nominal scenario
    - Slow degradation over time leading to groundwater release
    - Seismic and climate included
    - Contributions over all realizations averaged at each time step
  - —Disruptive event scenario (igneous activity)
    - Short duration, low probability, potential for high consequences
    - Requires special techniques to evaluate risk with reasonable number of runs
      - ° Convolution of expected doses for all possible events prior to evaluation time

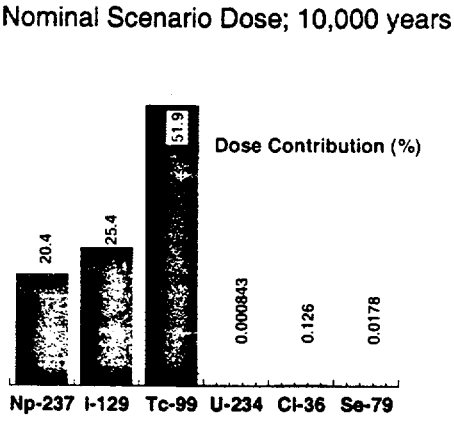
Nominal Scenario Results

- Initially Defective Failure:
  - —Average: 45
  - —Range: 1 - 88 [uniform]
- Well Pumping Varied
- 20 km Receptor Location
- No Corrosion or Seismic Failure Within 10,000 years
- Peak Risk 0.021 mrem/years at 9,769 years



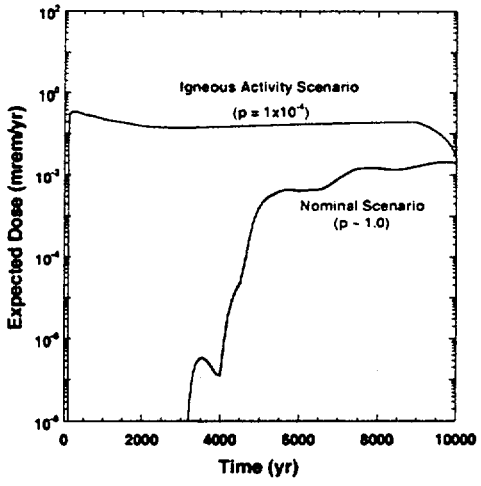
Nominal Scenario Results (continued)



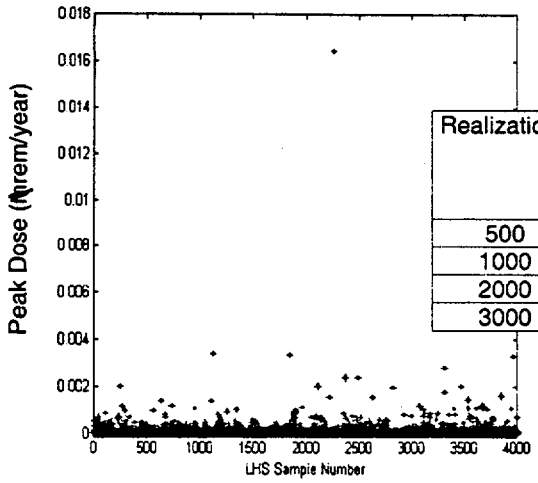


Disruptive (Igneous) Event Scenario Results

- Conditional Dose Computed at 12 Event Times (i.e., 4,200 Realizations)
- Peak Risk 0.35 mrem/years at 245 years
- Early Dose from Short-Lived but High-Activity Nuclides (e.g., ^{241}Am)



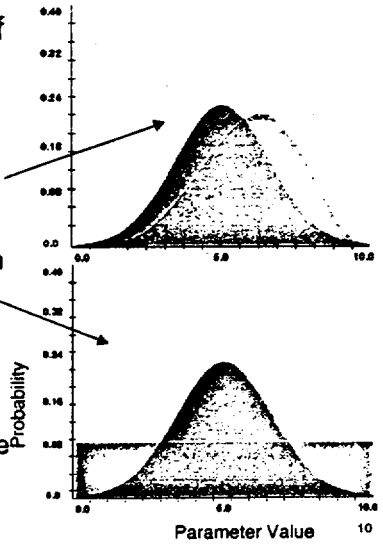
Stability of Peak Expected Dose



Realizations	Peak Expected Dose (mrem/year)	Peak Occurs at (year)
500	2.48×10^{-2}	10,000
1000	3.05×10^{-2}	8490
2000	3.24×10^{-2}	10,000
3000	2.46×10^{-2}	10,000

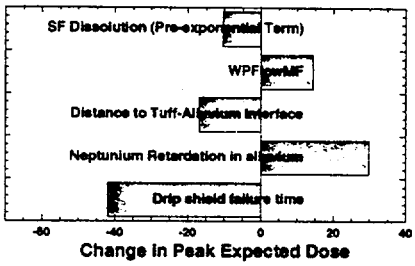
Distributional Sensitivity

- Relative Impact of the Change of Input Distribution
- Test Cases:
  - —Top 10 influential parameters
  - —Fixed range, but shift mean by 10% of the range
  - —Fixed range, but change distribution type
- Sensitivity Measures
  - —Change in peak expected dose
  - —Effective distance between nominal case and sensitivity case cumulative distribution functions

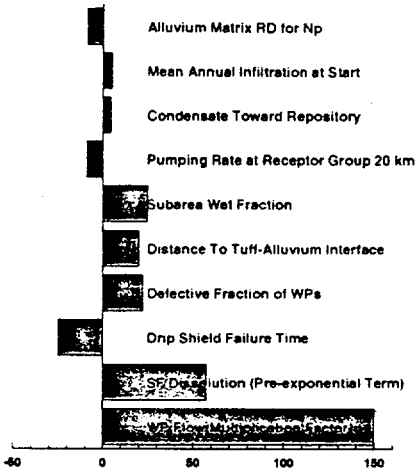


Distributional Sensitivity (continued)

- Nominal Data Set
- One Parameter Varied at a Time
- Fixed Range



Change of Distribution Type



Shift of Mean by 10% of Range

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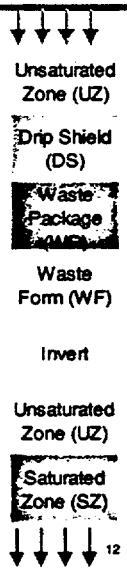
Barrier Component Sensitivity Analyses

- Barrier Divided into Barrier Components
- Sensitivity = Change in Performance Caused by Barrier(s) Suppression With Other Barrier(s) Active, or Barrier(s) Acting Alone With Other Barriers Suppressed
- Results of One-on, One-off, and Cumulative Addition Calculations Provide Different Insights
- Definition of System State for Barrier Suppression Problematic
- Not Required by Regulations



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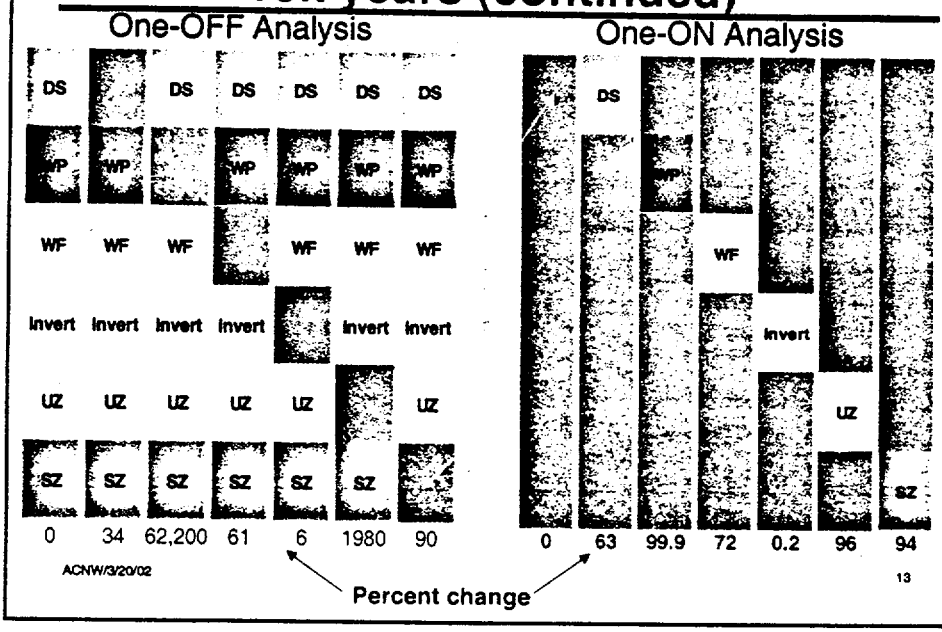
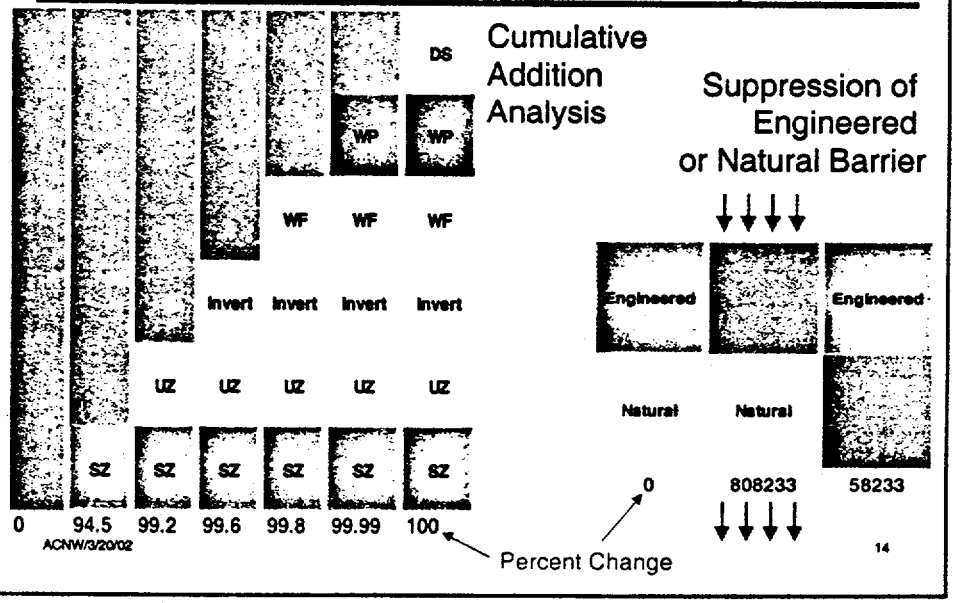
Barrier Component Sensitivity- 10k years (continued)



Barrier Component Sensitivity- 10k years (continued)



Parameter Sensitivity Analysis

- Nominal Scenario Only
- Determine Sensitivity of Parameters Singly and in Groups
- Statistical Methods Evaluate Sensitivity for Previously Calculated Pool of Vectors
- Nonstatistical Methods Direct How Models Are Sampled to Get Sensitivity
- Results Generally Based on Peak for Each Realization

Sensitivity Analysis Methods

- Statistical Methods
  - —Start with 4000 latin hypercube sampling vectors;10,000 and 100,000 years
  - —Regression of raw and transformed input and output variables
  - —Nonparametric tests
  - —Parameter-tree method
  - —Cumulative distribution functions sensitivity method (developed at the CNWRA)
- NonStatistical Methods
  - —Differential analysis
  - —Morris method
  - —Fourier Amplitude Sensitivity Technique
  - —Factorial Design of Experiments

Composite Statistical Method

- Look at 6 Statistical Tests for 4000 Realizations
- Factor Number of Times Variable Is Statistically Significant for Each Test, and Its Rank
- Develop a Single List of Top Parameters and Their Ranking

Rank	10,000 years	100,000 years
1	Drip shield Failure Time	SF Dissolution Model 2 Pre-exponent
2	Subarea Wet Fraction	Subarea Wet Fraction
3	WP Flow Multiplication Factor	AA_1_1 (corrosion rate parameter)
4	SF Dissolution Model 2 Pre-exponent	Alluvium Matrix RD for Np
5	Defective Fraction Of WPs in a Subarea	Tuff Alluvium Interface Distance
6	Condensate Toward Repository	WP Flow Multiplication Factor
7	Mean Annual Infiltration At Start	Alluvium Matrix RD for Pu
8	Condensate Removed	Mean Annual Infiltration At Start
9	Tuff-Alluvium Interface Distance	Precip. Multiplier At Glacial Max.
10	Well Pumping Rate	Well Pumping Rate

Top Parameters by Statistical Method

Factorial Design of Experiments

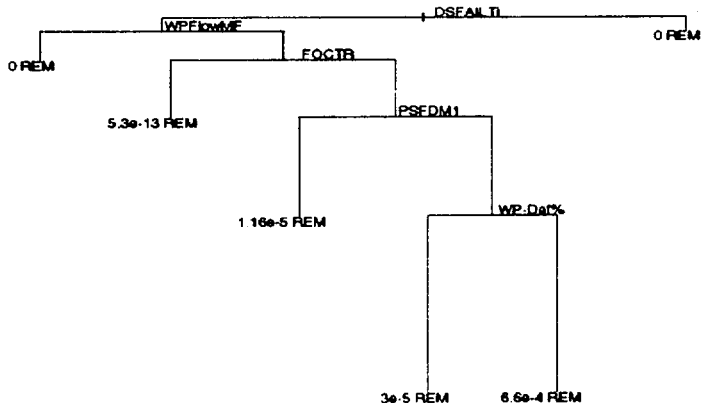
- Sample Each Parameter at Two Values; 5th and 95th Percentile of Distribution
- Would Require 2^{330} Runs (10^{94} years) for All Possible Combinations
- Fractional Factorial Design More Reasonable, but Ambiguous
- Perform Sampling Iteratively, Using Other Results to Reject Insensitive Parameters
- Advantages
  - — Systematic and potentially precise
  - — Easily interpreted with Analysis of Variance and trees
  - — Reveals interactions among variables
- Disadvantages
  - — Can be costly
  - — Doesn't cover entire ranges of variables

Factorial Design Results

- First Set of 2048 Vectors Identified 100 Potentially Sensitive Variables
- Reduced List to 37 Variables on Basis of Other Information From Runs
- Second Set of 2048 Vectors Identified 10 Sensitive Variables
- Full Factorial (2^{10} = 1024 Vectors) Identified 6 to 8 Sensitive Variables

Factorial Design Results- 10k years

Low parameter value ← → **High parameter value**



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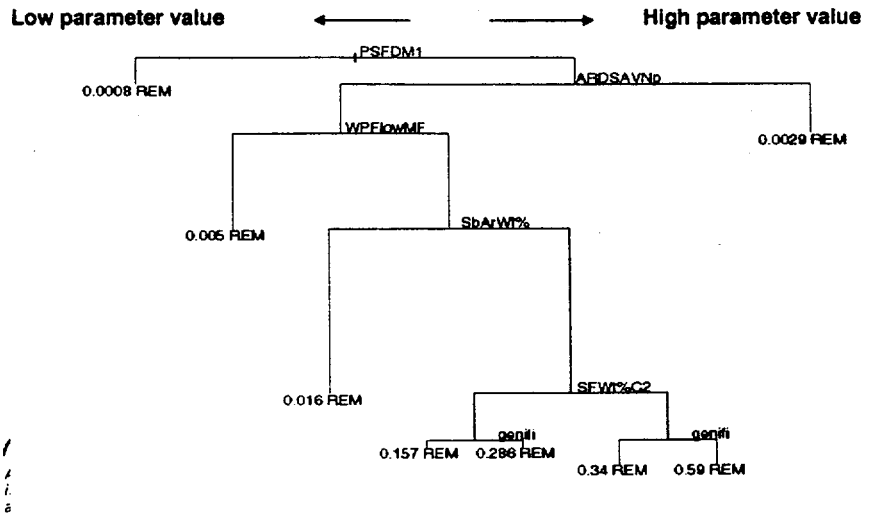
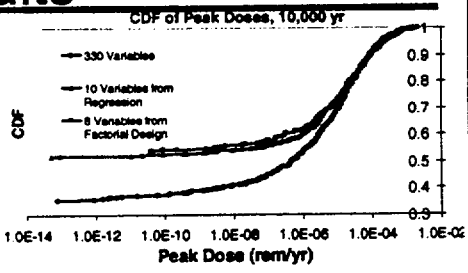
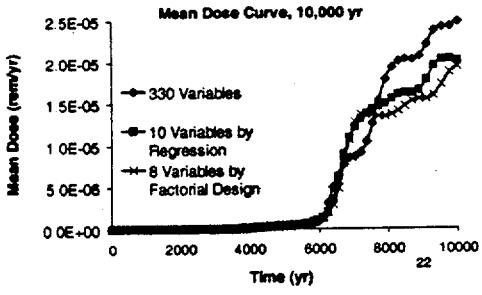
Factorial Design Results-100k years



Demonstrating Validity of Sensitivity Results

- Reconstruct Cumulative Distribution Functions of Peak Doses and Mean Dose Curve From Full Set of 330 Variables and Reduced Sets
- 500 Vectors With Reproduced Sampling of Each Variable
- Results Show Most Uncertainty Captured by Reduced Sets of Variables





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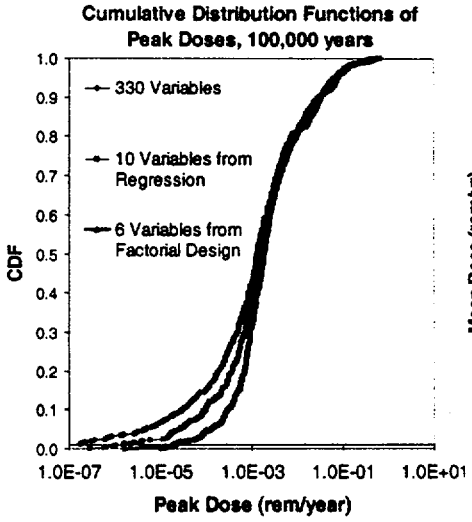
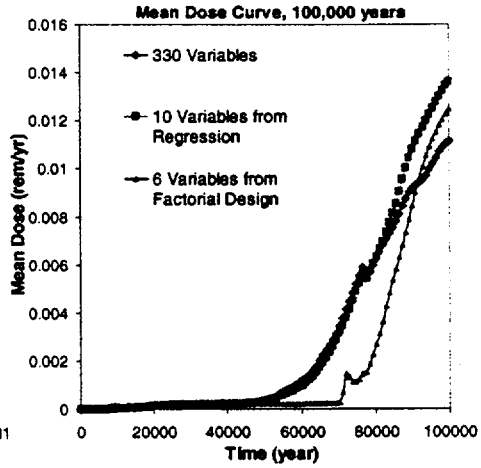
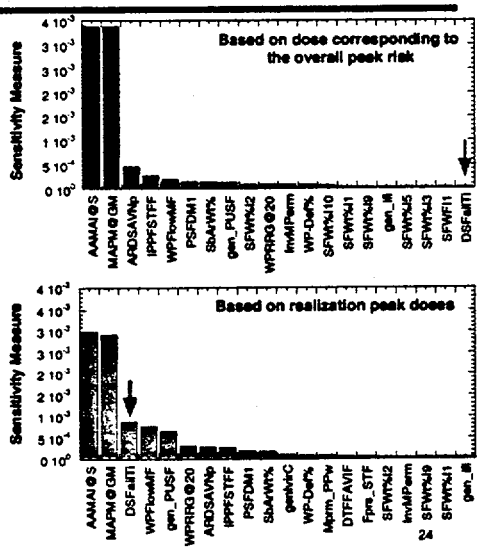
Demonstrating Validity of Sensitivity Results (continued)





Sensitivity Measures

- Two Options:
  - —(1) Dose from each realization at time of peak of mean
  - —(2) Peak dose from each realization
- Rankings Substantially Different
  - — No change in rank only for the top two parameters
  - — Four variables from Option 2 do not appear in results from Option 1 and the vice versa
- Option 2 Recommended Because the Sensitivity is Greater (beyond first two variables)



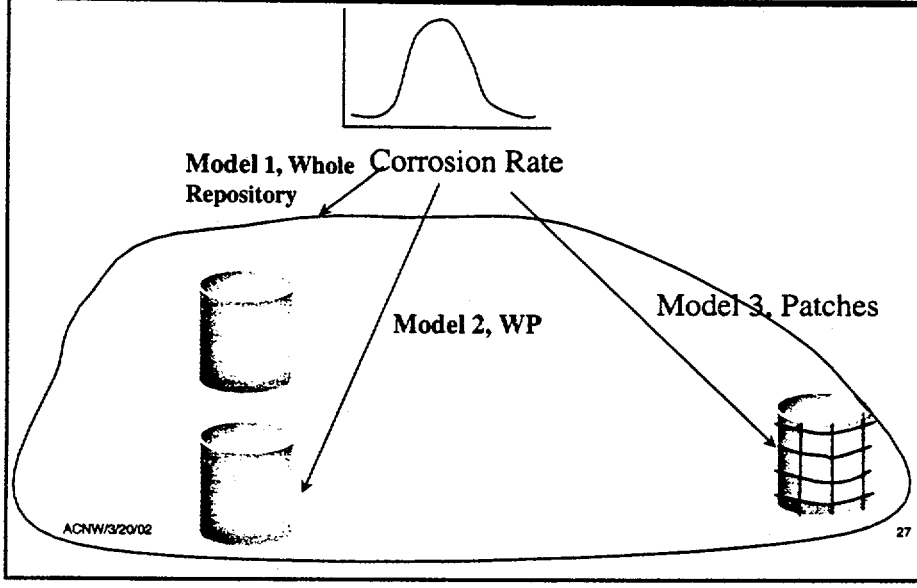
Treatment of Data Variability in Performance Assessment Modeling

- Experimental Data Uncertain Either Because of Lack of Knowledge (Epistemic) or Variability (Aleatory)
- Differences Between Epistemic and Aleatory Uncertainty Often Blurred
- Example: Treatment of Corrosion-rate Data for Waste Packages, and Its Effects on Dose

Treatment of Corrosion Rate Data

- NRC Model (TPA 4.1) Represents All Variability by Few "Representative" Waste Packages
- DOE Total System Performance Assessment Uses "Patch Failure" Model That Allows Significant Spatial Variability
- Corrosion Data Could Be:
  - — A fixed but uncertain rate (epistemic), or
  - — A spatially varying rate due to material and environmental variability (aleatory)

Demonstration Models- Three Conceptual Models



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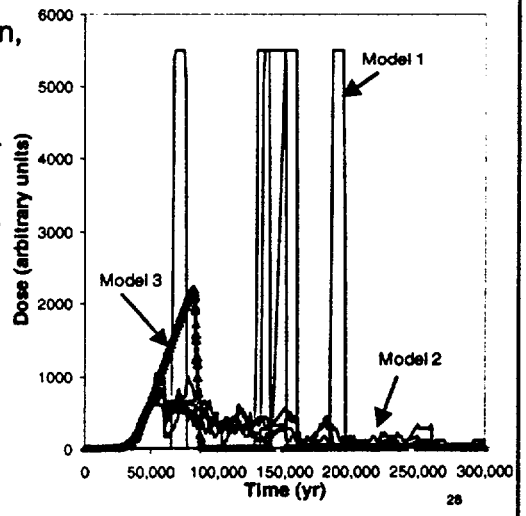
Results of Model Studies

- Doses From Model 1 Have High Peaks Within Realization, but at Widely Different Times
- Model 3 Doses Have Smaller Peaks, but Were Less Different Among Realizations
- Doses Averaged Over All Realizations (Peak-of-mean Approach) Sensitive to Uniformity Among Random Runs



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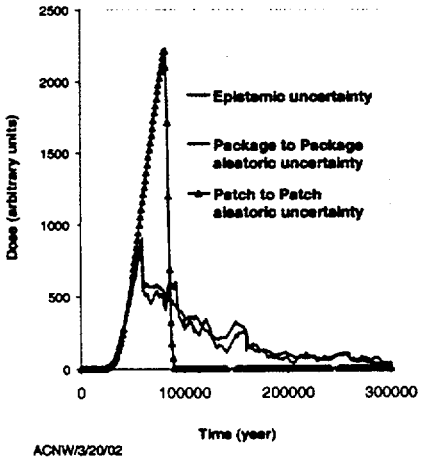
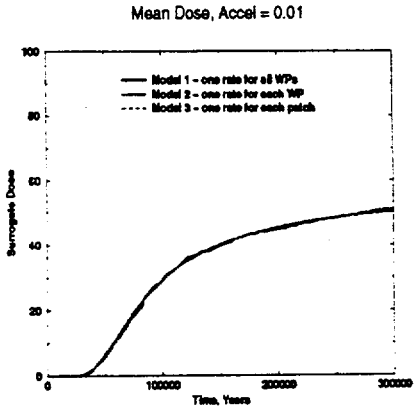
Results of Model Studies (continued)

Mean Dose, Base



Mean Dose, 100 time slower release



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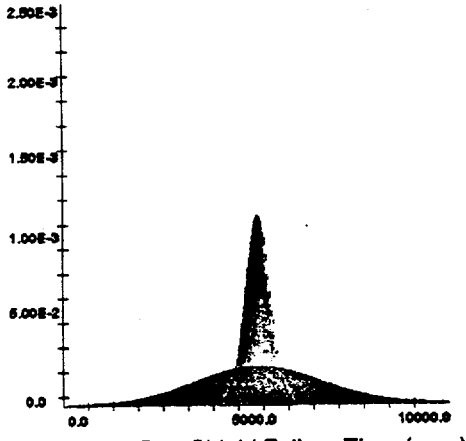
Risk Dilution

- From Inappropriate Use of Wide Distribution Range
  - — May reduce peak mean dose
  - — Caused by factors that affect timing of dose
- Example:
  - — Drip shield failure times with identical mean, but different ranges
  - — Narrow Range:
    0.051 mrem/year at 6,410 years
  - — Wide range:
    0.039 mrem/year at 10,000 years



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Preliminary Insights from Sensitivity Analyses

- Parametric Sensitivities for 10,000 years
  - — Factors controlling water/fuel contact dominate performance
  - — Most dose from low-retardation and long-half-life radionuclides
- Parametric Sensitivities for 100,000 years
  - — Waste packages usually fail; corrosion parameters not necessarily sensitive
  - — Fuel/water contact still important
  - — Retardation of neptunium important
- Barrier Sensitivity
  - — Both natural barrier and engineered barriers make substantial contributions

Additional Work in Progress

- Neural Networks for Statistical Sensitivity
- New Sensitivity Measures Consistent With Peak Expected Dose
- Efficient Distributional Sensitivity Methods
- Formal Analysis of Barrier Performance
  - — 29 of 64 analyses completed
  - — Tree structure and Analysis of Variance to show dominant sequences of barriers

Conclusions

- Parametric Sensitivities Provide Useful Risk Insights
  - — *Ad hoc* sensitivity ranking appears to work well
  - — Factorial design shows great promise in clearly defining parameter sensitivity and variable interactions
- Distributional Sensitivity Appears to be an Effective Approach to Identify Impact of the Choice of Parameter Distribution Shape and Mean
- Inappropriate Parameter Range may Lead to Risk Dilution
- Treatment of Uncertainty as Lack of Knowledge (Epistemic) or Variability (Aleatory) can Affect Peak Risk Calculated