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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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RELIABILITY AND PRA SUBCOMMITTEE

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TUESDAY, DECEMBER 1, 2015

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 8:32 a.m., John W. Stetkar, Chairman, presiding.

COMMITTEE MEMBERS:

JOHN W. STETKAR, Chairman

DENNIS C. BLEY, Member

RONALD G. BALLINGER, Member

CHARLES H. BROWN, JR. Member

MICHAEL L. CORRADINI, Member

JOY REMPE, Member

HAROLD B. RAY, Member

STEPHEN P. SCHULTZ, Member

DESIGNATED FEDERAL OFFICIAL:

JOHN LAI

ALSO PRESENT:

VICKI BIER, University of Wisconsin-Madison

ROBERT BUDNITZ, Lawrence Berkeley National Laboratory*

RICHARD DENNING, Consultant

ED FULLER, Office of Research

DONNA GILMORE, Public Participant*

MARVIN LEWIS, Public Participant*

EDWIN LYMAN, Union of Concerned Scientists

VINOD MUBAYI, Brookhaven National Laboratory

JACK VECCHIARELLI, Public Participant*

*Present via telephone

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Adjourn

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

8:32 a.m.

CHAIRMAN STETKAR: The meeting will now come to order. This is a meeting of the Reliability and PRA Subcommittee.

I'm John Stetkar, Chairman of the Subcommittee meeting. ACRS members in attendance are Harold Ray, Steve Schultz, Mike Corradini, Dennis Bley, Ron Ballinger and Joy Rempe. John Lai of the ACRS staff is the designated federal official for this meeting.

The Subcommittee will hear discussions on whether a revised societal safety goal is needed in light of the Fukushima Daiichi accident. We'll hear presentations from interested parties.

There will be a phone bridge line. To preclude interruption of the meeting the phone will be placed in a listen-in mode during the presentations and Committee discussions. One of the presenters, Dr. Robert Budnitz, will make his presentation on line and the line will be open for that portion of the meeting.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's meeting.

The Subcommittee will gather information, analyze relevant issues and facts and formulate proposed positions and actions as appropriate for deliberation by the full Committee.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register notice, therefore, we request that participants in this meeting use the microphones located throughout the meeting room when addressing the Subcommittee. The participants should first identify themselves and speak with sufficient clarity and volume so that they may be readily heard.

And I'd remind you all to please check and silence all of your little communications devices.

MEMBER CORRADINI: Mr. Chairman?

CHAIRMAN STETKAR: Yes, Dr. Corradini? Turn on your microphone, doctor.

MEMBER CORRADINI: Ah, it is.

CHAIRMAN STETKAR: I'm sorry.

MEMBER CORRADINI: I just wanted to alert the Committee that I participated with Dr. Bier on the Idaho -- the INL research program that will be presented today, so I will limit my remarks there to only clarification.

CHAIRMAN STETKAR: Thank you, sir. Anything else from any of the Committee members?

(No audible response)

CHAIRMAN STETKAR: I hope that all of the L-tryptophan has worn off after Thanksgiving turkey and that we can be actively engaged during this meeting.

And with that, I guess, Vinod, it's up to you.

MR. MUBAYI: Okay. I'd like to thank the Committee for inviting me to share some views on this topic. I've been asked to begin with a disclaimer that nothing that I have to say here today implicates or represents in any way the views of the U.S. Department of Energy or Brookhaven National Laboratory.

So with that disclaimer, I began in putting together this presentation -- the first slide just represents the current quantitative health objectives which is one way in which the -- which are come out of the Safety Goal Policy Statement. And the whole emphasis of safety in the NRC has been limiting the health risk from released radioactive materials in reactor accidents, ionizing radiation, limit those kinds of risks. And the quantitative health objectives were formulated in a way that those risks would be limited to something that was small of an appropriate background risk, namely early fatality due to all kinds of things like traffic accidents, lightning strikes, whatever, and latent cancer fatalities that were limited based on the background rate of latent cancer in the U.S. And just to remind people, the early fatality individual risk is calculated in terms of the average individual within one mile and the latent cancer 10 miles, etcetera.

Now, I began to think of the usefulness of these goals, as one of my former colleagues in the audience will recall, almost 30 years ago because my business was to do consequence analysis, which I've been doing for a long period of time. And we were doing these NUREG-1150 studies. And we always calculated the doses and health effects after an appropriate protective action like evacuation or sheltering, etcetera, was carried out.

So all the concerns of that period, as I recall, going back to the late '80s, early '90s when we were running these codes, would be devoted towards those early releases, those 30-minute and one hour cahuengas, as they used to call them in the old WASH-1400 days, in which you would get people exposed while they were evacuating under the plume. They would be given no shelter. So you'd get large number of health effects: fatalities or whatever, because of these releases. And we used to place a lot of emphasis on what was appropriate. Should they shelter in place? Should they do this? Should they evacuate and so on?

So as I told one of my colleagues -- he couldn't quite believe that you did consequence analysis after you took into account the effective evacuation. And if those who are veterans of the NUREG-1150 days will recall, the draft NUREG-1150 which was put out in like '87 or so, had 90 percent or 95 percent; I forget the exact number, of the population that participated and this gave a result that seemed a bit "high," quote/unquote. So in the final NUREG-1150 we evacuated 99.5 percent to push that consequence down to something that looked -- had a better optics associated with it.

Okay. On the next slide I just point out how the safety goals -- how societal risk --

CHAIRMAN STETKAR: Vinod, we have a question.

MR. MUBAYI: Sure.

MEMBER CORRADINI: Are you going to show that effect to -- that's an interesting tidbit I don't remember. So --

MR. MUBAYI: I haven't gotten evidence of it, but I can -- anybody who's interested, I can look up the old documents.

MEMBER CORRADINI: Okay.

MR. MUBAYI: It's just something that happened. The 99.5 percent you'll find in NUREG-1150 in the appropriate volumes of the consequence analysis. The draft one goes back to the time I began this business. You can find it in the literature, I'm sure.

MEMBER CORRADINI: Let me ask a different question. In the current planning for emergency planning what is the assumed percentage that refuse to --

MR. MUBAYI: I think it's 99.5.

MEMBER CORRADINI: That refuse to evacuate.

MR. MUBAYI: In the early '90s we were given a job of reassessing the siting issues, and we went through a lot of calculations of consequence code to address different aspects of having people evacuate at a slow speed, having 95 percent versus 99. It's NUREG/CR-6295, I think. And then we did it with the re-baselined NUREG-1150 source terms.

MEMBER CORRADINI: Okay. Thank you.

MR. MUBAYI: All that information is in the literature.

But I really want to focus on this. So societal risk is addressed in two ways, as people who read the Safety Goal Policy Statement will recall, that the risks of nuclear power generation should be comparable to or less than other technologies for generating power, and nuclear power should not be a significant contributor to other societal risks. But what societal risk itself is is not defined or elaborated on in the policy statement.

Now I briefly referred to this. The QHOs have been estimated in many level 3 PRAs starting with NUREG-1150, which satisfied the QHOs by a wide margin taking into account uncertainty, too. Looking at the 95th mean and the 5th percentile you find the safety goal is satisfied by a fairly wide margin, although I think only two of the five NUREG-1150 plans addressed some external risk. The other three were only internal events.

Now more recent studies like SOARCA, which is not a complete PRA, but it more or less reaches the same conclusion by even wider margin, and the mean point is actually not hard to understand, that the accidents that previously used to evolve in a short period of time. As a result of more recent research a lot of the old type of fast releases have been more or less eliminated, as it were, or their frequencies have been driven down to very low levels. And it's just a better understand, as it were, of the severe accident timing that has led to this result. Because everybody in the 10-mile or one-mile area is long gone. And once they are outside, they've evacuated, the code does not attribute any further exposure to that close-in population. There is still exposure within the 50-mile zone, etcetera, but once you divide out as you calculate the average individual risk, you divide the dose that has been received by the total population, the number becomes very, very small.

Now the actual accidents, as we see, either no release or minor release like Three Mile Island or a major release like Fukushima also satisfied the QHOs by a wide margin. And I put in this last tantalizing statement. I'm not sure, because even Chernobyl from what is known from the latent cancers, etcetera, that have been incurred, probably satisfies the QHOs.

Next slide. If we just look at Fukushima --

MEMBER BLEY: Vinod?

MR. MUBAYI: Yes?

MEMBER BLEY: You were guessing at that one, I think. I think I've seen some studies out of the Ukraine that would disagree with that, but I'll pass those on to you at some point, if you'd like.

MR. MUBAYI: Let me say about Ukraine studies. In 1998 EPA had a major meeting in Washington, D.C. to which they invited some very belligerent Ukrainians and Pols, and I gave a talk at that meeting on this sort of stuff. And I was attacked for being inhuman at that talk because the problem is that there is no registry or record. So either a million people died after Chernobyl or 10 people died, and any number in between. The 10 persons is the WHO, the 10 thyroid cancer, young people in Belarus. That's on the record. The rest of the millions who perished could have perished from any cause.

I mean, the whole problem with the Ukraine is whenever there is no good registry of cancers, something like is maintained by the Atlanta-based whatever it -- the Federal Government here, you can make any claim at all. I mean, you can pretty much say -- and I'm in no position. I've never been to the Ukraine, so I can't testify to their reliability or lack of it, but from what I can see the -- going by WHO numbers, which is an international organization, has published data, etcetera -- going by these reports, yes, it would have satisfied. Going by various Ukrainian activist groups like who showed up at this meeting, you can probably -- the whole entire -- that's -- in that next decade what you do at Chernobyl. So you can take what you want.

Now the Fukushima consequences, we all know that a huge number died drowning by the tsunami, but we are confronted with this, what I consider is a paradox, that the QHOs are satisfied even without factoring in release probability. We all know there's zero early fatality. It's five years since any acute radiation exposure. And the studies that I've seen show that there is not measurable increase in latent cancers that is expected. Maybe they could be because -- but then of course we get into this whole controversy of the LNT, the linear no-threshold hypothesis where even the tiniest amount of exposure over a million people is going to lead to some expected value of latent cancers, etcetera.

But the QHOs are definitely satisfied. We don't even think about it because we divide by the population. But on the other hand there is a huge societal impact. There is a long-term relocation of 100,000, 90-odd-thousand people. The cost of recovery, much of which involves decontamination, is likely to be in excess of 70 or $80 billion. That's on the estimates that we've been doing a little bit of work on the side gathering this information.

MEMBER CORRADINI: So just to be clear, the 76 billion is your estimate?

MR. MUBAYI: No, there are various estimates. There's a paper that's I think written by Rich Denning and myself that you probably may have got copies of as a -- that estimate is in there.

CHAIRMAN STETKAR: Yes, that estimate is 50 billion, I believe.

MR. MUBAYI: Right, it says 50 billion, but there's an update to 76 that we'll probably do correction. And it's in an NRC document right now. I can give you the ML number. I don't have it with me. It's that document that looked at the venting, the improvements in the venting for Mark 1 and 2 of hardened vents. There's a draft reg analysis that gave an updated code for the Fukushima costs.

MEMBER CORRADINI: So can I ask a different question?

MR. MUBAYI: Yes.

MEMBER CORRADINI: Maybe I don't remember the paper, but I'm sure John will show it to me.

So what was the total cost of the

tsunami and associated seismic event in terms of recovery nationwide compared to the 76 billion? It seems to me that would be a comparison point one would to know.

MR. MUBAYI: I don't have a number on that unfortunately, what is the cost of recovering from the tsunami, but I think that the 76 billion is mostly due to decontamination. Part of it is the long-term relocation, paying for that. And part of it, which our codes unfortunately ignore, is the cost of disposal. You're gathering together a huge amount of contaminated soil, contaminated trees, leaves, orchards, etcetera, and there's a significant cost of disposal associated with that.

And in that cost benefit analysis of the hardened vents there's a draft NUREG out that gives the updated estimate. That's where I got the 76 billion from.

MEMBER CORRADINI: Okay. Thank you.

MR. MUBAYI: Now the other thing is that if somebody recalls reading -- there's been some anecdotal evidence in the New York Times of deaths from -- which are totally non-radiation, but just as a result of evacuation. And I think there's a number like 1,000-odd deaths, older people, etcetera, from the stress of the evacuation. Some were evacuated from hospitals or nursing homes. And there's an article in the New York Times that came out roughly three weeks ago, or a month ago and that reported anecdotal evidence of these kinds of -- just the stress of the long-term evacuation on the public.

So the question that then comes up is by adopting risk acceptance criteria that are based on the QHOs alone, are we really addressing the relevant risk?

The other questions that are related: Society does expend significant resources on protecting people from radiation exposure. How far should it go? Right now the way we calculate this stuff in our codes is to look at the EPA. For a severe accident like we did in NUREG-1150 or it's done in SOARCA, etcetera, 2 rem in the first year, 500-millirem a year thereafter. That's taken from the EPA manual. And that's how some people think that that's not enough. We should keep them -- the habitability criterion should be changed. And that involves -- but the bottom line is that protective actions do involve long-term disruption of people's lives; Fukushima is a very good example. With multifactorial impacts and huge costs.

So about five or six years before Fukushima I started thinking about this issue. Having run these -- calculated these QHOs as we did Zion at B&L and in the NUREG-1150 program. After that I was involved in other such studies for the NRC over the last 20 years or so. And so the QHOs always get satisfied. And then we look at this other impact. So we started thinking about what does it mean? Are there other -- should we look at other background risks in order to derive a goal that is perhaps more meaningful than the QHO, which seemed to be pretty much automatically satisfied?

And especially now that we have a better understanding of severe accidents, we have decreased these 30-minute and one-hour releases that were in the old WASH-1400, and even to some extent in NUREG-1150 those steam explosion, alpha mode of failure, etcetera. We essentially factored them out of the whole understanding of how accidents -- so it takes many hours to boil the inventory and so forth.

You can look at the Fukushima timeline. It's a very good illustration of the most severe accident that can possibly occur. And it takes many hours in which we can evacuate people, etcetera, which we'll always do. So somehow I started thinking of other phenomena that had somewhat similar impacts to what I envisage the aftermath of a severe accident like Fukushima. And the natural phenomena hazards like hurricanes and earthquakes, floods come to mind. And we do have large-scale evacuation, and especially this started at the time of Katrina.

When I started thinking about this, that, hey, this looks like -- and the reason was my wife was in the military. She was based in Hattiesburg. She's a doctor in the military. And she was based for a couple of years -- that was a time when Katrina happened. So actually, I went there. I used to go and visit her every few months. And I saw all these boats in the trees and stuff like that and said this is maybe -- this is what happens when people have to leave en masse from a whole area that's devastated by some disaster like that.

And so the similarity of that struck me as I'm looking at where can I get some data? And there are various risk metrics that one can think of. Number of evacuated and relocated. It's one possibility. But many of these events could be to provide a comparison to try and subsume them in some sort of a common metric. So cost, one thinks about is something than can be calculated.

And I was lucky that I came across a paper that was written by Roger Pielke and his associates at the University of Colorado that gave a database of hurricane severity and cost from the year 1890-something to current, like 120 years. And so since hurricanes happen with a frequency of once every couple of years, severe hurricanes, one can derive -- it's like deriving a background that sort of said, hey, I'm going to apply that 0.1 percent of some background number. Let's look to hurricanes to see. And I wrote an initial paper on it that was published in one of the ANS proceedings about a year or two before Fukushima. And that was given by one of my colleagues at that time, presented there. There was an even earlier paper in 1995 on cost of accidents, etcetera, that was presented by another colleague in Hawaii who's in the audience today.

But finally we got some numbers together, and there was a paper presented at PSA-13 where I got together in the same session with Rich

Denning, and we were looking at these things from like in complementary terms. So the costs of destructive hurricanes and severe accidents updated from a nuclear power plant design that we did in NUREG-1150. This is --

MEMBER REMPE: Before you get into the data --

MR. MUBAYI: Right.

MEMBER REMPE: -- if you'd go back to that other viewgraph. This viewgraph along with other viewgraphs that I've seen in the materials that are going to be presented today causes some confusion on my part, and maybe you and other presenters can help me alleviate that confusion.

I'm having trouble defining the control boundary if one does a societal risk goal. There's like apples and oranges here. First of all, if you go to trying to compare nuclear reactor accidents with -- which there's benefits associated with a nuclear power plant, and if you go beyond just health effects and you start talking economic disruption of people's lives, well, there's also some benefits in their lives because you've built that plant. And I don't see perhaps a benefit with an earthquake and some of the other phenomena you're comparing this with. And then I --

MR. MUBAYI: Oh, there are --

MEMBER REMPE: I've got more.

MR. MUBAYI: Yes, sure.

MEMBER REMPE: So where do you draw the control boundary on the society? Is it just people that are near the plant, or is it the whole country that benefits from the power, or just the people near the plant, which there's also benefits to the community. When they shut the plants down, there are a lot of communities that are dealing with the loss of tax dollars and things like that. It's not just the folks that work at the plant.

And so I'm having trouble with the control boundary and where does society versus individuals end? And also how can you compare an accident to -- from a plant with natural phenomena and -- do you understand my concerns when I read all this material? And you guys have been studying a lot longer than me, and maybe you can help me --

MR. MUBAYI: Sure.

MEMBER REMPE: -- eliminate my confusion.

MR. MUBAYI: Sure. The boundary that

we draw is on the number of large scale evacuation. The cost that is associated is keeping those people evacuated for a long time and the loss of tax dollars, businesses, etcetera that have to shut. The second --

MEMBER REMPE: But if you do that, then you need to consider the benefits associated with that plant.

MR. MUBAYI: Yes.

MEMBER REMPE: Because you don't have benefits with an earthquake.

MR. MUBAYI: Oh, yes, you do. It turns out that whenever there's a severe earthquake or a hurricane, etcetera, government/public money will come in and will fund a lot of improvements. I mean, lot of communities, there's a substantial amount of funds that pour in. And matter of fact, there have been studies that do the tradeoffs of how much benefit is gained by the cleanup that is done, improved structures that are created, improvements that are done in a particular area. That happens with all natural phenomena.

MEMBER REMPE: I would say that happens, too, though, with what's happening over at Daiichi. They are building up a large industry with drones and robots and --

MR. MUBAYI: Absolutely.

MEMBER REMPE: Yes, so that happens, too.

MR. MUBAYI: Yes.

MEMBER REMPE: So one needs to have a bigger control --

(Simultaneous speaking)

MR. MUBAYI: Yes, I'm just saying that in terms -- there is a similarity that if we are comparing the disruption of a large scale societal disruption, there are costs and benefits associated with any disruption. How they evaluate those costs and benefits is a matter of detail that we need to look at. What is included and what is excluded? In my view the major aspect of the costs, apart from all the other societal improvements that might occur in that particular area, because now there will be new industries or whatever that will come in, is the costs of decontamination, is the costs of disposal and the costs associated with keeping a large number of people relocated for X number of years.

Those are the same things that happened at Katrina. I mean, now New Orleans is arguably --

there's been an improvement in the levee system, there's an improvement in various areas. Government has come spent the money. So there's always some tradeoff. But the costs that were associated with keeping people uprooted, dispersed for considerable periods of time I think has some similarity. How these boundaries are to be drawn, what exactly is to be considered, what should we exclude.

The same thing applies to the safety goals, by the way. Early fatalities. Now that the risk of traffic accidents has gone down, there are considerably fewer traffic accidents than before. Homicides have gone up and other things have gone up. The same thing happens in any large scale societal comparison. These boundaries are not fixed and eternal. They're always shifting. And they'll continue to shift as society changes over time.

MEMBER CORRADINI: So can I just get one clarification since you brought up three things and I'm sure you're going to get to an end point? So you said disposal, decontamination and essentially long-term --

MR. MUBAYI: Relocation.

MEMBER CORRADINI: -- relocation.

MR. MUBAYI: Yes.

MEMBER CORRADINI: So it seems to me the half-life of this with a nuclear accident is longer than the half-life of this due to a natural disaster. So isn't it the half-life of how long people -- it's not the money. I mean, the way I view it is -- you identified three things, but it's not the money, it's not where you bury it. It's how long people are essentially displaced that tends to be the thing that people remember from any sort of accident --

MR. MUBAYI: I think --

MEMBER CORRADINI: -- whether it be natural or not. So isn't it the half-life of how long people are displaced?

MR. MUBAYI: Yes, I think that's one way to set a boundary. That could be a further study of this. I don't think there's an immediate answer to your question. We have studied it for a little while as sort of a side thing. It's not funded research that we went and elicited opinions from a wide number of people. The two of us have been doing it in our spare time, as it were.

But I think there's definitely an issue

of what was raised of how elastic these boundaries are, where to draw them, and what are the costs that are really to be considered? The one thing in the nuclear disaster is I think the whole issue of removing a lot of contaminated thing and putting it somewhere. That does involve a cost to society that has to be taken into account.

Yes, the number of years people stay -- after Katrina it took about five to almost a decade for -- five to seven years of relocation of substantial amounts of people. Some of them never came back. Some of them came back, etcetera. Fukushima might have -- they're anticipating something of 2019 of 2018 based on some of the things that I read in the accounts of the accident. So, yes, five to seven years, about that much.

MEMBER BROWN: I have one question relating to Joy's question relative to benefits. Nuclear power plants have benefits relative to what they produce. And you equated the fact that, well, earthquakes have benefits because all this money pours in to fix or correct or improve the local community. I have a hard time putting my hands around that being a benefit since it has to come from somewhere. It's not free.

And this idea that government money flows in and it's free from somewhere is a little bit of a hard spot. It detracts from some other part of the economy. It's got to come out from some other programs, particularly if it's unexpected. There is no cash, there is not little carved out area in the overall federal budget which says, oh, we're going to address some of these catastrophes periodically, therefore we will have $70 billion sitting around that's, quote, "free money." But somebody's got to put that in there. It's not free money. So I'm just throwing that out.

MR. MUBAYI: I think I would fundamentally disagree with you.

(Laughter)

MR. MUBAYI: And I'm not an economist. And see, they imagine it in terms of a gigantic input/output table of transactions. What happens typically is that, yes, government money is invested and leads to something new that wasn't there before. And it's hard to express it in -- you know, I'm not the right person to choose the language, but I have read some of these things that in an input/output sense there are flows in the economy from one sector to the other. So land suddenly becomes more available somewhere. New industry will come in, benefit the local community and so forth.

I think we are just putting forth the germ of an idea here. I think we need some economists now to come and grapple with these issues. The nuclear power plant has a benefit that was producing power, and that was benefit. And at the end of the day that power will be replaced. Some other plant will come in as we do replace when power calculations and produce power for that area.

But I think that there are definitely benefits from any disaster, and they may be hard to quantify. There may be difficulties, but the concept is very clear in the economic literature if you read about these things done by economists from the input/output sense of the way in which they do these calculations.

Okay. This is actually an interesting table. That was derived from Dr. Roger Pielke and his associates. And it's been updated a little bit from this paper. It's extracted from this paper that Rich Denning and I have been working on. And as you can see, what they tried to do was to not only account for inflation, but they accounted for a lot of -- to construct a time series of this is a lot of effort that they went into trying to establish similar grounds of comparable damage, what it would be like in current or close to current year dollars of what damage had been incurred a century ago. And there's a whole paper that describes their approach and so forth.

But you can see that the -- all I wanted to do initially was to establish that these events -- as you can see on the next thing, these are some costs associated with updated to near current year 2012 of the various sequences in the NUREG-1150 Zion study. And we looked at offsite costs of these different scenarios and the largest ones are sort of in the range of a hurricane damage. They're like $90 billion or $80 billion, etcetera. And I think that some of these are underestimated, because the MACCS code has a decontamination cost model that is essentially derived from WASH-1400.

And there were some minor changes made that are less than transparent what the basis of their -- I've been looking into it for some other reasons lately. But that model definitely needs to be updated.

CHAIRMAN STETKAR: Vinod?

MR. MUBAYI: Yes.

CHAIRMAN STETKAR: The staff is currently working on updating the -- I know the cost estimates as a basis for their regulatory analyses. Are you aware of that effort?

MR. MUBAYI: I'm not supposed to be aware of that effort, let me put it that way.

CHAIRMAN STETKAR: Okay. Then I'll ask someone else.

MR. MUBAYI: Yes.

CHAIRMAN STETKAR: Thanks.

(Laughter)

MR. MUBAYI: I've been told to stay away from those efforts.

CHAIRMAN STETKAR: If there's anybody in the audience, eventually I'm going to get an answer to that question. But apparently Vinod is not supposed to know about this, so --

MR. MUBAYI: Not officially, yes.

CHAIRMAN STETKAR: -- I'll bring it up with someone else later.

MR. MUBAYI: So we drew a CCDF based on these and --

MEMBER CORRADINI: So, can I just clarify the --

MR. MUBAYI: Sure.

MEMBER CORRADINI: -- don't go back to the slide, but just to clarify, the numbers on the previous slide from Zion you're saying are underestimates because of --

MR. MUBAYI: Decontamination model alone.

MEMBER CORRADINI: That it? Not disposal and not essentially relocation costs?

MR. MUBAYI: The relocation costs are included in he MACCS. Now one can argue about the number.

MEMBER CORRADINI: Okay.

MR. MUBAYI: But the decontamination costs are also included, but I think there's a serious error in the actual numbers that needs to be changed. And I believe that some effort is being done to change them, although I'm not officially supposed to know about those efforts.

MEMBER CORRADINI: Okay. Fine. Thank you.

MR. MUBAYI: But I think that it does need to be changed. And I think it's a more serious error than the relocation cost, which may be off by roughly a factor of two. But this one is off by a factor I think of like 10, or one order of magnitude. So it's just a matter of detail.

I have the CCDF. If we look at one plant alone and we look at the hurricane cost, then obviously we have a considerable amount of leeway that we could meet a 0.1 percent goal. If you take the hurricane cost as the background risk and do the same thing as we did with the safety goal of 1.1 percent of latent cancer, or whatever, then we could meet the goal for one plant. For 100, if we do all the plants; because just multiply those things, and do it as a global thing, then I think we would -- if we do improve the decontamination cost, that 0.1 percent could be much, much tighter. I'm not sure if we would meet it, but that's something for the future.

So I've sort of summarized this thing that the single plant cost risks would meet a one percent goal with hurricanes as the background, but it might be a bit more difficult to meet it if we extend it to all the reactors.

Just some concluding remarks, to which I believe that this session should look at these issues. The last time I looked over the various NRC staff documents and NUREGs, etcetera, that last time a nuclear power plant societal risk was considered seemed to be about 15 years ago. There's a bunch of SECYs that I have listed. I think I made copies. I don't know if the staff distributed them. They tentatively address societal risk, but every time they do it in terms of collective dose. That is the health effect is the only thing that's in mind. So they do it in terms of collective dose instead of individual risk, but they didn't really come to any conclusions.

On the other hand there is a statute on the books that talks about an extraordinary nuclear occurrence, and it's codified in 10 CFR 140. And they give a bunch of definitions of these. This seems to be not a reactor accident at all, but something that has to do with probably a fuel fabrication plant or something that is a non-reactor because of the numbers that are cited in the statute. But it may be if there is a societal goal that is brought forth in terms of dollar costs or something, certainly a reactor accident should quality to be an extraordinary nuclear occurrence. So maybe that could be a statute that could serve as a vehicle. That's just a guess on my part.

That's all I have to say. Thank you very much.

CHAIRMAN STETKAR: Thank you, Vinod. Any other members, questions for Vinod?

(No audible response)

CHAIRMAN STETKAR: If not, thanks a lot for your presentation and insights. And we'll call up Rich Denning.

MR. DENNING: Okay.

CHAIRMAN STETKAR: By the way, the microphones are -- so make sure that it's going to pick you up.

MR. MUBAYI: Yes, okay. Incidentally, you had the question, Mike, with regards to what the cost was as far as recovering from a flood. And I don't know that answer, but if you do want to look and ask the question if you value lives at $5 million per death, what would the societal impact be, and that's $100 billion, 20,000 lives. So that gives you at least some perspective there.

Okay. There are some aspects of this that are a little repetitive, and I'll go through those things quickly to get to the things that I really would like to bring up. And some of those things, Joy, that you raised I'll definitely address in an afternoon session as well, because I think there are some real questions about cost benefit, although I think that the focus of this is really on what's an acceptable risk rather than cost benefit. But I definitely want to get into the cost benefit because that really is an important issue as well when you look at this.

Okay. So we got into this looking at the impacts of Fukushima Daiichi and this question of public perception of 20,000 deaths, but the radiological impacts are extremely small. And I think that it's clear that that's true. I think that the radiological impacts could have been more severe than they were if the wind hadn't been blowing towards the ocean. But it's also true that the land contamination would have also been more severe if the wind hadn't been blowing towards the ocean for a significant period of the release.

Now there are two sides to the story for me. One of the sides is that the societal risk is bigger than I think we had perceived, but the other side of it is that I think that we have overemphasized the health risk to the public from the radiological impacts of accidents. And being a major contributor to this in WASH-1400 I bear some personal responsibility for that.

I think that to a large extent it goes back to WASH-740 and the very conservative assumptions that were made there, the estimate of thousands of early fatalities by vaporizing the core. WASH-1400 we saw -- we put that more into risk perspective, but we also dramatically overestimated the potential for early fatalities and also latent cancer fatalities.

I think that we are partially responsible for the feeling that the public has that the operation of nuclear power plants represents a radiological health risk to them when the reality is not only that it's very small as far as early fatalities, it may just be a total fabrication not representing reality at all. And we'll talk about that a little bit more.

So I think there are two sides of this. And the one side of it is that we have to better recognize how small this human health risk is of nuclear power plant accidents as it affects regulations. The other side of it is we have to also recognize the potential significance of land contamination.

MEMBER CORRADINI: So, Rich --

MR. DENNING: Yes?

MEMBER CORRADINI: -- let me ask -- I guess I understand what you're saying, but isn't the land contamination based on health? So why would we worry about the land being contaminated? It wasn't health-related.

MR. DENNING: So basically what we do is we worry about the land contamination. We move people out of the way, we incur costs due to that to protect their health. So there's a relationship back to health.

MEMBER CORRADINI: Okay.

MR. MUBAYI: Okay. So I see three aspects of the Safety Goal Policy Statement, one of them related to the no significant additional risk to life and health from the radiological consequences. And I see the societal risk in two parts, the first being should not be a significant addition to other societal risks. And I'll try to define other societal risks the way I see it. And there's a problem in that there isn't a good definition of what societal risk truly is. But then there's the other that it should be comparable to or less than the risks of generating electricity by viable competing alternative technologies.

That item, No. 3, that's the easy part. Paul Scherrer Institute spent a lot of money looking at that. Others have. And when you look at these relative health risks of nuclear power plant accidents in terms of things like the dollars per loss of years of life or the dollars per fatality and you compare them with fossil fuels, they're a lot less than fossil fuels. You compare them with the renewables, and they're very similar but very small. Those costs are extremely small relative to the potential benefits of nuclear power.

So I think the No. 3 element of it -- I think that's the easy one. I think the one that people really haven't look at adequately is this comparison of -- should be no -- this no significant addition to societal risk.

We're familiar with the QHOs. And what I'm really suggesting is a quantitative safety objective that relates to those: the early prompt fatality, the latent cancer fatality. People talk about the two.

Oh, and here's the NUREG-1150 risk perspective, of course, for that that shows that -- the bar up at the top there is the safety goal, which recognize that's 0.1 percent of the background. And then you see these uncertainty bands that we calculated for NUREG-1150 with the mean being the -- the top of the bar is 95th percentile. Most people can make comparisons with the mean. You see at least another factor of 100. So we're looking at 10 to the 5th difference between those risks as predicted from NUREG-1150 versus the background risks of either -- for early fatalities, the accident risks for latent cancer fatalities, the cancer risks basically.

And as we look at SOARCA, it indicates that even in NUREG-1150 we've been extremely conservative, or we've been conservative relative to that. And we draw the conclusion here that nuclear power plants do not represent a significant additional risk relative to the comparable risks. But I think it really goes significantly beyond that. If you look at SOARCA and the sensitivity studies that they've done, they just don't see early fatalities in those events.

And so, I'm going to get off that bit

right now and talk about that a little bit more this afternoon when we look at, well, how might we change regulations and what are the implications of changes and regulations?

Okay. So comment about QHOs. Something that has bugged me for a very long period of time, and that is that the latent cancer fatality goals referred to a societal risk goal, but it isn't societal risk. It's just another individual health risk. It's an appropriate one to look at latent cancer fatalities as a health risk, but you look at individual risk. You don't look at the integral as we would for a societal risk. And I think that Fukushima makes it clear what a societal risk is; I mean, to me anyway, and that's the effect of land contamination, relocation, loss of production. And then the question is if we establish the quantitative societal objective, what would it look like?

MEMBER RAY: Question: When you refer to loss of production --

MR. DENNING: Yes?

MEMBER RAY: -- how big a scope are you looking? The entire country, the entire world, or what?

MR. DENNING: Yes. So basically what I'm thinking about loss of production is in that area in which you have contaminated products that can't be sold, which people move away and they can't farm land and stuff like that.

MEMBER RAY: So you're not thinking of what I'll call societal reaction that would shut down plants, that sort of thing?

MR. DENNING: No, that's those secondary effects. And then there's -- and that of shutting plants, like the cost of shutting -- of what was done in Europe and other places. Should we consider that as an impact of Fukushima? And I would say no. When you ask the question of the Japanese shutting down 50 plants and the effect of that on their society, which was a direct impact. The biggest direct impact is probably that cost.

MEMBER RAY: For sure.

MR. DENNING: I haven't included that, but that gets into the very difficult question of what do you include and what don't you include? And I'll talk about that a little bit more. But let me say when I get down to saying what we actually did here is that I only took the one year production. I didn't take successive years of not being able to use that. And part of the reason for that is when you talk to the economists, you get into this question of resilience. And what you see is you displace people and what happens is if you take away their Pepsi Cola, then they drink Coca Cola and Coca Cola gets a big boom. And that also gets into kind of one of the questions that Joy is asking, and that is where do you draw the boundaries on this, because indeed when people come in and decontaminate, we count it as a positive in the gross domestic product. We put people to work. And we count that as improvement, whereas the reality is we know that isn't really improvement in our society.

So I think when we look at this, and you'll see how I've looked at it -- but you really have to have a large number of people with different perspectives that get together and make the decisions. If we're going to say this is our background societal risk, we have to have a lot of people with different perspectives involved in that and make discussions.

Now when we make the comparison --

MEMBER BLEY: Well --

MR. DENNING: Yes?

MEMBER BLEY: -- let me sneak in a question because I've wondered about this some. You mentioned to Mike that the reason we relocate people is to protect their health, but these massive relocations: Katrina as well as --

MR. DENNING: Yes.

MEMBER BLEY: -- Daiichi, must lead to severe emotional/psychological problems, maybe even to deaths by suicide and that sort of thing. I've never seen any data on that. Have you looked at that at all?

MR. DENNING: Well, we've thought about it. Now one of the things that we have seen and which -- and Bob Budnitz later may comment on, are if you look at what happened with some old people at Fukushima where they were evacuated quickly and there are attributed deaths to that. I think one of the problems with our need to change perspective relates to evacuation and relates to offsite response. To lots of people it's -- evacuation to them seems essential, whereas the reality is in the vast majority of the time you're better to just stay where you are, have people come in and in an orderly fashion move people. Because again, we've gotten overly concerned on LERF; and we'll talk about that a little bit more, when the reality is that the likelihood of these kinds of events, if they're even real at all out there, is so small that we think about evacuating people and doing it quickly.

So as far as the psychological impact of moving people away from their homelands, that's a real effect. There's no question. And it may be different in different societies. In the American society, which is very transient, it probably isn't nearly as big of an effect as it is in other societies. And I haven't tried to capture that, but it is something that people might try to capture.

Now I'm going to show you some risk results in terms of what I call -- mean risk is just fatalities per year averaged, the expectation value of the risk curve. I think the CCDF is more important -- is more appropriate for those things that I see as being comparable. I see things that are societally disruptive. Big things. Ten billion dollar or more kinds of events that can have an effect on society as being the elements of societal risk. And CCDF is the way to really do that.

So getting into this. And so, all of this work is unsupported. Most of this stuff is stuff that I did on the Internet and this kind of stuff. And early on I did -- when I looked at the nuclear part of it, I used RASCAL. And you're going to see Vicki, when she talks, she used RASCAL. In my analyses I had to use MACCS because I had doses that extended beyond -- important areas of concentration that extended beyond 50 miles.

But on the non-nuclear part, if you look at the big contributors, the things that really affect our society are -- wars and epidemics are really big. I reconstructed it from U.S. data. I went back to the entire history of the United States as captured in the Internet, and there are parts about that that are questionable. Does that really reflect today's risks and things like that? But in some respects I think it does.

Now I didn't do things -- like I used $5 million per life. It's a pretty typical value. It's arguable. I didn't look at injuries and the cost of injuries. The $5 million per life enters into wars and epidemics there. And those are big potential things that can really dramatically affect society. And if you look at the bottom curve and you look at that point that's out on the right-hand-most part there, that's 500,000 lives lost in the Civil War. And then you see the other wars in that blue curve. And then you see it on that -- epidemics.

Epidemics are another big thing that can really affect a lot of people. But when you go back and look and ask yourself, well, what could have happened or what may happen, and you look historically at other countries and you look at many millions of people that have died in wars, you look at future potential for wars and millions of people could die, what you see is what's a pretty flat CCDF that goes out to very -- in a very flat way out to large things.

Now things that we think of as being -- now I liked Vinod's comparison with hurricanes, because there's a lot of similarity in the shapes of the CCDFs between hurricane costs and nuclear power plant costs when we get to those. You see all these things that we think of as minor catastrophes or maybe aircraft crashes, stuff like that, things like that, things that happen all the time. And they fill in that left-hand part of the curve. But it is important to recognize that as far as these kind of disastrous kind of the things, the $10 billion things, they happen pretty frequently. I mean, $10 billions isn't such a big thing.

Did you have a question?

MEMBER CORRADINI: Yes, I do.

MR. DENNING: Yes?

MEMBER CORRADINI: You can call on me. So I understand how you got the X axis. You took essentially, whether it be a prompt fatality or some sort of latent effect --

MR. DENNING: Yes.

MEMBER CORRADINI: -- multiplied it by 5 million, and that was your number on the X axis.

MR. DENNING: Yes.

MEMBER CORRADINI: The Y axis, you told us to look to the right and said -- what was the right? The Civil War?

MR. DENNING: So that was the Civil War.

MEMBER CORRADINI: Okay. So now --

MR. DENNING: So that's --

(Simultaneous speaking)

MEMBER CORRADINI: -- how did you compute the number on the Y axis for the Civil War?

MR. DENNING: Okay. So I had to look at the number of wars that occurred. So I had a period of time. So I had wars occurring back to the Civil War. So that was --

MEMBER CORRADINI: So 1776 to now?

MR. DENNING: Yes, that's right. I think actually it was probably the Civil War to now, but yes.

MEMBER CORRADINI: And then, but help me out a little more.

MR. DENNING: Yes, yes.

MEMBER CORRADINI: I'm leading you down the path of --

MR. DENNING: So for each of those I looked at years that I had and then I looked at the -- basically per year what were the consequences per year.

MEMBER CORRADINI: So you normalized it to the time since the Civil War? That's what I'm still --

MR. DENNING: So it's over the period of time that I had data.

MEMBER CORRADINI: Okay.

MR. DENNING: So, okay, the period of time that I had data, right. Most of it's

1900-to-now kind of stuff. And so it's a little more current than that, but I didn't do things like correct for population. So if you look at the fraction of the population that died in the Civil War, I didn't do a correction, which would have raised it.

So I think that the real societal risk is bigger, and the real societal risk really extends out there to really big things.

One of the things it gives you a feeling is if you look at the gross domestic product is 1.5 times 10 to the 15th. So if you're looking at this curve, that's out here.

CHAIRMAN STETKAR: Rich, you have to stay somewhere near the microphones so --

MR. DENNING: That's out there.

CHAIRMAN STETKAR: You can use --

MR. DENNING: I pointed at 1 times 10 to the 15th, which is off the graph to the right.

MEMBER SCHULTZ: Rich, how did you evaluate then recessions? Was that just a monetary evaluation?

MR. DENNING: Oh, yes. Yes, and we'll be taking recessions out of the paper, because they don't like recessions, but we were in the middle --

when I did it we were right in the middle of this recession. I recognized maybe that's the same kind of thing. And basically I looked at dips. and I took into account dips as being lost dollars, stuff like that. So maybe it's just an animal that doesn't belong in there. So when you see the final results you're not going to see recessions in there.

MEMBER SCHULTZ: Okay.

MR. DENNING: Okay. Let's move on then, because I want to talk about the way I did --

MEMBER CORRADINI: Sorry to drag you back --

MR. DENNING: Yes, sir.

MEMBER CORRADINI: -- but since you put the numbers up --

MR. DENNING: Yes.

MEMBER CORRADINI: So if somebody said if I start arguing about dollars, it's a never ending argument, your point back would be, well, if you don't like 5 million, put in 10 million. Yes, what I'm trying to get at --

MR. DENNING: Yes.

MEMBER CORRADINI: -- what I'm worried about is when I start dealing with dollars --

MR. DENNING: Yes.

MEMBER CORRADINI: -- economic consequences, there will be a never ending discussion of what is the --

MR. DENNING: Right. So clearly you would have been happy if I'd used utils, because --

MEMBER CORRADINI: Utils?

MR. DENNING: Utils.

MEMBER CORRADINI: Utils is good.

MR. DENNING: Well, utils in un-interpretable. So the question is how do you value life --

CHAIRMAN STETKAR: For the record, that U-T-I-L-S.

MR. DENNING: U-T-I-L-E-S, right.

PARTICIPANT: What is it?

MR. DENNING: What is it? It's a way to

-- that you compare different kinds of things in multi-attribute utility theory. When you get into these very --

MEMBER BROWN: (Off microphone).

(Laughter)

MR. DENNING: Yes. Well, I'm lost, too.

MEMBER BROWN: I apologize for that.

MR. DENNING: I can say it. Multi-attribute utility theory.

MEMBER BROWN: Okay. So you don't understand it either then?

(Laughter)

MR. DENNING: Okay. So anyway, it's just a way to put things, things that aren't really the same on a comparable basis with weighting factors and things like that.

MEMBER RAY: Well, but wait a minute.

MR. DENNING: So I use --

(Simultaneous speaking)

MEMBER RAY: Hold on a second.

MR. DENNING: Yes, sir.

MEMBER RAY: Ultimately you do get to cost benefit, and cost is denominated in dollars. So somewhere along the line when you finally get to the decision making about what to do, it has to be put into dollars. So I'm not sure that putting them in dollars here is inappropriate.

MEMBER CORRADINI: Okay. Well, I'll wait until the discussion to argue that. But, okay.

MR. DENNING: It's just a question of

how you would weight otherwise.

MEMBER CORRADINI: Well, I mean, it's fine if you want to articulate it some other measure, but I'm just saying that if any of this ever translates into doing anything, the doing of it is measured in dollars.

(Laughter)

MR. DENNING: Now I understand what you mean.

MEMBER CORRADINI: And I guess my argument back is it doesn't have to be.

MR. DENNING: Yes.

MEMBER CORRADINI: It could be measured in different units or different things that are surrogate to dollars. Because what Rich had said at the very beginning, which is -- I guess I'm focused on land contamination. As soon as I deal with that, is that
-- you're going to somehow roll that number and put it somewhere underneath that purple umbrella?

MR. DENNING: Sure.

MEMBER CORRADINI: And as soon as I start doing that --

MR. DENNING: Yes.

MEMBER CORRADINI: -- I get in a big

argument about what the dollar cost is. And so that's what worries me.

MEMBER RAY: Okay. Hold on. Let him and I talk for a second.

(Laughter)

MEMBER RAY: All I'm trying to do is look to the point where you're ultimately saying thus we have to do something and in what's acceptable in the plant. And that will be measured in dollars, I'll guarantee.

MEMBER CORRADINI: Could be. Doesn't have to be. Could be.

MEMBER RAY: In today's world I think it is. Yes, going back in time you would just say I want a diversity, I want redundancy. I don't care what it costs. But that day is probably gone.

MR. DENNING: Okay. Now onto nuclear power plant risk. And basically this is the part where -- so I had a simple model, 104 U.S. plants. And basically the way I did this is I came up with a very -- and this is very simplistic. And risk analysts may look at this and say how can you really characterize 100 nuclear power plants with such a simple event tree, in a sense, in which we look at only 4 kinds -- levels of release there with -- and these are conditional probabilities. I'm going to separate out totally the frequency of nuclear power plant accidents and I'm just going to look at this as being the distribution --

CHAIRMAN STETKAR: Rich?

MR. DENNING: -- of releases. Yes.

CHAIRMAN STETKAR: Except for the fact that in bypass that must be the relative fraction of whatever your core damage frequency that was associated with an interfacing system LOCA accident, because the conditional containment failure probability for that event is one.

MR. DENNING: Yes. No. So this is --

CHAIRMAN STETKAR: So you do have some measure of frequency in here. It's kind of snuck in.

MR. DENNING: Well, no, I think it hasn't, because basically what I've done is I've pulled that all out of the so that the relative probability of bypass is in there.

CHAIRMAN STETKAR: Oh, I'm sorry.

MR. DENNING: Okay?

CHAIRMAN STETKAR: It's not a relative probability. If the frequency of the containment bypass initiating event is 10 to the minus 9 per year, that's the frequency of core melt with containment bypass. If it's 10 to the minus 5 per year, it's the frequency of core melt with containment bypass. That 4.2 times 10 to the minus 3 must be a ratio of the interfacing system LOCA initiating event frequency to some frequency of core damage that you used.

MR. DENNING: Yes.

CHAIRMAN STETKAR: It must be.

MR. DENNING: That is. That is --

(Simultaneous speaking)

CHAIRMAN STETKAR: So frequency has snuck in here.

MR. DENNING: Well --

CHAIRMAN STETKAR: It has, because --

MR. DENNING: Well --

CHAIRMAN STETKAR: -- because that value --

MR. DENNING: -- but when you multiply it the total frequency, I think you'll be happy.

CHAIRMAN STETKAR: The importance is I couldn't figure out how big a -- and we'll get to -- the reason I wanted to raise that is that if that particular contribution is very important to your overall results --

MR. DENNING: Yes. It's not.

CHAIRMAN STETKAR: -- that because it's 10 percent of the cesium release fraction. That I couldn't figure out. So we'll go forward from there.

MR. DENNING: Well, okay. So then as far as the release fractions are concerned, basically those are my perception of -- so basically these relative probabilities of kinds of releases are NUREG-1150. And then I weighted PWR as 60 percent, BWR as 40 percent. And then, but those release fractions are what the values were for basically these kinds of releases in a draft version of SOARCA.

In the final version of SOARCA the bypass release dropped from 10 percent to a lower value due to significant credit given for retention within an auxiliary building and within piping. And it seemed to me that I had to really recognize that maybe that was true for that particular scenario, but I remember Fukushima clearly, what happened to the reactor buildings in those cases. Now, obviously there's not as much hydrogen that's produced in a PWR as in a BWR, but they weren't there anymore.

And I remember the arguments we used to have in the old days during our discussions between the NRC and industry during IDCORE times over whether you would get that much credit. So I felt I had to recognize some potential for that, so I stayed with the draft SOARCA version of that release. As it turns out that doesn't have a big effect.

Okay. So basically I had access to a graduate student who could do MACCS calculations for me for a year, and who got his master's degree based upon this. And he's now at FirstEnergy in the Risk Group there. But basically he ran MACCS calculations for me. And what I wanted to look at was very focused on contamination due to cesium.

If you look at the different radionuclides, iodine has potentially significant societal impact, at least for a short period of time. And there was a period of time at Fukushima in which for a day or so there were questions about whether certain water was contaminated, drinking water was contaminated to a level. But those go away fairly quickly in comparison with this kind of situation we have at Chernobyl where you've got this huge land area that still is isolated there.

Okay. So I wanted to look at what the effect was of different sites, because we recognize clearly that's going to be important. So what I did was I looked at four actual U.S. sites. I used the wind roses for those, but I used just one set of annual meteorologies based on one actual site. And basically that's that site over there. You see probabilities, wind speeds. And I obviously collapse down from like 15 groups into like 4 groups. So this is a collapsed version of that as well. And I recognize that at some point if you want to really follow the approach that I'm suggesting here that it's going to take a lot of dollars to undertake a really full study to look beyond the effect of cesium as we see here.

Okay. And so basically we ran MACCS. And we did not use the MACCS consequence model. So what happened was -- so the student really broke down all of these areas into ZIP codes and looked at the amount of productivity in a ZIP code, number of people within a ZIP code and this kind of stuff, and calculated that.

Okay. Now as I was saying before, I isolated this question of the fraction of releases from core damage frequency. What's the probability per year that -- or the frequency with which you have core damage accidents? Because that's something -- and this is the only uncertainty. Lots of uncertainties here. This is the only uncertainty I did. But I think that -- particularly to the non-PRA believer I think this is particularly important, and maybe to the PRA believer as well. So clearly there's a lot of uncertainty there.

So on the one side I said, okay, if I talk to PRA analysts and said, so, what would you say the lowest possibility is for the average frequency per year of core damage for plants in the U.S.? And I used 1 times 10 to the minus 5 per year, because we see some plants that say they're 1 times 10 to the minus 5 per year, but there certainly are plants that are in the region between 1 times 10 to the minus 5 and 10 to the minus 4. And maybe there are plants that are even above 10 to the minus 4. Maybe. I'm not sure.

But I don't think I'd find any analyst that would say the average of core damage frequency is lower than 1 times 10 to the minus 5 per year. Anybody here want to say I think that the average core damage frequency in the United States is less than that? Anyway, I don't think they'll say that. Okay. When you include all things like fires and seismic and stuff like that as well as stuff --

Okay. Then on the high side, when we looked at NUREG-1150, Zion in the first run there was 3.3 times 10 to the minus 4 per year. And I've used that. But I had more than that for the reason for that. The other reason that I used that was there's 10,000 years of light water reactor experience in the world today. And I verified that for myself. I heard that. I verified it for myself going back through old Nuclear News and trying to estimate how many years various plants operated. Now it included VVERs as light water reactors. And if a light water reactor ever deserved to melt down, a VVER did. And none of them have yet, amazingly.

But anyway, I included --

CHAIRMAN STETKAR: I'm sorry. Why is that?

MR. DENNING: VVERs?

CHAIRMAN STETKAR: Yes, why is that?

MR. DENNING: Well, the VVER-440s that shut down were pretty poor plants.

CHAIRMAN STETKAR: Why is that?

MR. DENNING: No containments, first of all. The VVER-440s. Very little redundancy.

CHAIRMAN STETKAR: What's the basis for that claim?

MR. DENNING: Well, from my basis it is --

(Simultaneous speaking)

CHAIRMAN STETKAR: I've looked at VVER-440, so I'm curious about this.

MR. DENNING: Yes, so I spent a lot of time on Armenia's VVERs -- are not the same, but --

CHAIRMAN STETKAR: Yes, they weren't.

MR. DENNING: -- the state of those plants was really poor. VVER-1000s are closer --

CHAIRMAN STETKAR: No, no, no. We're --

MR. DENNING: Yes, the original

(Simultaneous speaking)

CHAIRMAN STETKAR: VVER. You made a statement and I'm trying to understand the basis for that.

MR. DENNING: My impression from those is that there was very little redundancy. If they did melt -- I've seen the computers that they used in those days. They were pathetic. They were --

CHAIRMAN STETKAR: Technically I'm trying to understand that statement.

MR. DENNING: Yes.

CHAIRMAN STETKAR: Because I've looked at several VVER-440s over all of Eastern Europe and I found they did have redundancy. In fact, they had time constants in terms of time to do things that were much longer than most U.S. plants.

MEMBER RAY: Because they had an awful lot of water.

CHAIRMAN STETKAR: Because they had an awful lot of water. So I'm curious about your statements that they deserve to melt.

MR. DENNING: Well, it was probably more from the viewpoint that if they had a severe accident there was no containment.

CHAIRMAN STETKAR: Oh, if they did? Yes.

MR. DENNING: If they had a severe accident, there was no containment.

CHAIRMAN STETKAR: Well, but if --

MR. DENNING: Yes. Okay. Nevertheless. Yes. No, I'm sorry.

CHAIRMAN STETKAR: I'm just trying to make sure that when we make statements that they have actual technical basis. So in your opinion I understand --

MR. DENNING: My opinion --

CHAIRMAN STETKAR: Okay. Thank you.

MR. DENNING: -- they were riskier than our current plants in the United States.

Okay. So that's the range that I used there, the high and the low for core damage frequency. So I'm sorry, I didn't give it -- so 10,000 years of reactor experience. And so for light water reactors there have been either two events or there have been four events, depending upon whether Fukushima is one event or three events. So I kind of took the log mean there. So even I'd say for the person that's really not a believer in PRA numbers on core damage frequency, there is some rationale to look at that.

Okay. I also added in some other things, and I'll go quickly over that. So we added in -- so we also considered events like TMI where there's no containment failure but where there are significant costs. Estimates were $5 billion for the cleanup costs for that, which I included $10 billion for scenarios with containment failure associated not with the land contamination, but just the cleanup of that specific area themselves.

And then looked at decontamination costs based on some actual bids for decontamination projects in Japan. But one of the problems we had with decontamination costs applied to the United States was it was clear that to some extent decontamination is a cost benefit question. At Chernobyl the cost benefit was there's a lot of area there that we're just going to leave contaminated. In Japan the decision is we're going to decontaminate everything. If it were in the United States, it's quite possible that there are areas in the United States where it just wouldn't make sense to go in and try to decontaminate woods and stuff like that.

So anyway, I put it on a population basis. That doesn't have a big impact other than when I'd look at --

(Simultaneous speaking)

CHAIRMAN STETKAR: Rich, before leave that slide --

MR. DENNING: Yes.

CHAIRMAN STETKAR: -- I had questions on a few of these, because they're --

MR. DENNING: Yes.

CHAIRMAN STETKAR: -- I think I want to understand some of these things as I read the paper and thought about the results. First of all, you said that your slave labor graduate student did a comprehensive survey of ZIP codes and correlated things, but you only actually used four sites in your analysis.

MR. DENNING: Yes. Yes, I did.

CHAIRMAN STETKAR: What were those? Can you tell us what those four sites were?

MR. DENNING: I don't think I should tell you what they are, but what I'll give you --

(Simultaneous speaking)

CHAIRMAN STETKAR: I know you did them geographically.

MR. DENNING: I did them geographically, and they were the logical ones that you might --

(Simultaneous speaking)

CHAIRMAN STETKAR: Okay. So we won't get that. Now, wait. No, no. Back up.

MR. DENNING: I'm sorry.

CHAIRMAN STETKAR: Back up.

MR. DENNING: I'm sorry.

CHAIRMAN STETKAR: Back up.

MR. DENNING: I'm sorry.

CHAIRMAN STETKAR: Back up. The second and third bullets there --

MR. DENNING: Yes.

CHAIRMAN STETKAR: -- the 10 billion and 5 billion are on site cleanup costs, are they not?

MR. DENNING: They are.

CHAIRMAN STETKAR: Are those appropriate to include in a societal risk calculation?

MR. DENNING: That's a good question.

CHAIRMAN STETKAR: Because I think they are included in your results.

MR. DENNING: They are.

CHAIRMAN STETKAR: And they seem to skew the overall results, at least at the low end of the curve. The high-frequency low ends of the curve.

MR. DENNING: Yes, they could.

CHAIRMAN STETKAR: They determine the results.

MR. DENNING: They could at the low end, yes.

CHAIRMAN STETKAR: But those are the

frequencies that most of the public will relate to in some sense. I mean, the --

MR. DENNING: Yes --

(Simultaneous speaking)

CHAIRMAN STETKAR: And a real question about whether they should.

MR. DENNING: Yes. So when we talk looking at mean risk -- actually I show the two risks. The mean risk, you see --

CHAIRMAN STETKAR: Don't worry about time. We're okay now.

MR. DENNING: -- that these risks are extremely small. So this $5 billion with these core damage frequencies is just a very small number.

CHAIRMAN STETKAR: I'm not particularly arguing about the --

MR. DENNING: Yes.

CHAIRMAN STETKAR: -- numbers. I'm --

MR. DENNING: But I did include them --

CHAIRMAN STETKAR: -- thinking about the philosophical --

MR. DENNING: -- and I do think that --

CHAIRMAN STETKAR: -- impact --

(Simultaneous speaking)

MR. DENNING: -- and, no, I had -- and I recognized the philosophical argument there as to when the utility, if it's a utility that pays for it, is that really public funds or is it not? Does it really affect our economy or not? But again, $5 billion events -- $5 billion is not really important particularly in the overall perspective that we have here. But I agree one could take that out.

CHAIRMAN STETKAR: It will be though when you present your final graphics. And I just want to set the stage for understanding it could be when you present the final graphics and how those might be interpreted by the public.

MR. DENNING: Yes.

CHAIRMAN STETKAR: Right.

MR. DENNING: Okay. That's fair.

Okay. So let me get to just the results here and show you some things. Okay. So there are the four sites that we looked at. These are the consequences. These are the CCDFs normalized basically to the 3.3 times 10 to the minus 4. And you can see that there is a significant difference. And people that are familiar with CCDFs recognize that having the long ledge out there before the curve really is a big impact. It's about a factor of four impact on the overall versus the average. So siting is important here.

And then here's the comparison. Okay. So here's the societal risk. And I've used 0.1 percent for the goal here and obviously there's a historical relationship there with the other values of 0.1 percent, but I could have used 0.1 percent on the mean, as the mean goal. If you use that and you ask from a mean analysis looking at the mean costs, monetize costs of nuclear power plant risks, does it satisfy a societal goal, I think you would easily satisfy it on the mean because that far right end of the curve here has a big effect on that mean.

CHAIRMAN STETKAR: But the shape of your green uncertainty curve --

MR. DENNING: Yes.

CHAIRMAN STETKAR: -- is still at the lower end where there seems to be the implication that the U.S. nuclear fleet --

MR. DENNING: Might not --

CHAIRMAN STETKAR: Clearly does not --

MR. DENNING: Well --

CHAIRMAN STETKAR: -- based on this graph, if I were interpreting this.

MR. DENNING: Well, no, that depends again on whether you're a believer in 3.3 times 10 to the minus 4 or 1 times 10 to the minus 5.

CHAIRMAN STETKAR: Right.

MR. DENNING: Yes. Right. Right. And --

CHAIRMAN STETKAR: But without the 5 and $10 billion --

MR. DENNING: It's the last --

CHAIRMAN STETKAR: -- if I pull that out, it would change the whole shape of that green curve at the low end where you see the largest discrepancy.

MR. DENNING: The largest discrepancy. I agree. Now as we start -- so this has no decontamination cost in it.

CHAIRMAN STETKAR: Right.

MR. DENNING: As we look at high decontamination costs, which based on Fukushima, what we're seeing now, may indeed be it, you see that low end of the curve differential seems to spread out there more over --

MEMBER CORRADINI: So, Rich, I'm sorry,

you and John are conversing about this, but maybe I've lost it.

MR. DENNING: Yes.

MEMBER CORRADINI: The green hatched region is an uncertainty between what and what, between 3.3 times 10 --

(Simultaneous speaking)

MR. DENNING: And 1 times 10 to the minus five. And that's the only uncertainty that I --

(Simultaneous speaking)

CHAIRMAN STETKAR: Multiplied by 100 --

MR. DENNING: Hundred plants.

CHAIRMAN STETKAR: -- plants.

MEMBER CORRADINI: Multiplied by --

CHAIRMAN STETKAR: That's why it's up around --

(Simultaneous speaking)

MR. DENNING: -- 100 plants.

MEMBER CORRADINI: Okay.

CHAIRMAN STETKAR: -- 10 to the minus 2-ish.

MR. DENNING: Yes.

MEMBER CORRADINI: Yes, I understand. Okay. That part i got.

MR. DENNING: Good.

MEMBER CORRADINI: Right. So the next step is in the green curve you have decontamination costs?

MR. DENNING: I didn't in the first curve.

MEMBER CORRADINI: Oh, did not?

MR. DENNING: Did not.

MEMBER CORRADINI: No?

MR. DENNING: No decontamination costs.

MEMBER CORRADINI: And then in the purple curve you do, but it's offsite decontamination?

MR. DENNING: Oh, yes. Yes, this is offsite decontamination.

MEMBER CORRADINI: Based on the MACCS number?

MR. DENNING: No, not on MACCS. Based upon some dollars that came from bids in Japan for that. And then that seems to be verified by the crude things that I've seen as to what the decontamination costs were.

CHAIRMAN STETKAR: Well, didn't you go -- one of the -- you index the decontamination cost to --

MR. DENNING: The person.

CHAIRMAN STETKAR: -- population displaced.

MR. DENNING: Yes. Yes.

CHAIRMAN STETKAR: And is that -- I start to think about, okay, I got 10 acres of farmland somewhere that has a family of four --

MR. DENNING: Yes.

CHAIRMAN STETKAR: -- sitting in their farm and I have to decontaminate that. Now, I got to take 10 acres and I've got a block of apartment buildings that has 1,000 --

MR. DENNING: Yes. Yes.

CHAIRMAN STETKAR: -- people living in them. Does that mean that it's going to cost me 250, 300 times more to decontaminate that 10 acres of land --

MR. DENNING: Yes.

CHAIRMAN STETKAR: -- with the apartment block on it?

MR. DENNING: So if you really narrowed it down like that, John, and look at an apartment building and stuff like that, then the only thing that the person -- number of people really has to do with it says, yes, you're going to decontaminate that area. So it didn't -- so basically what we're looking at are population regions and looking at like in New Jersey what's the population density of New Jersey and what's the population density of South Carolina, for example, or things like that? And it was clear that you're going to -- higher population density areas you're going to decontaminate. And lower population density areas, there's some fraction of it you may not decontaminate, or you're not going to decontaminate --

(Simultaneous speaking)

CHAIRMAN STETKAR: It's a different way of looking at it.

MR. DENNING: Yes. But --

MEMBER RAY: Well, wait.

MR. DENNING: Yes?

MEMBER RAY: I just want to reiterate what my understanding is, that we're only looking at -- these costs pale in comparison to lost production costs, but the reason those aren't included is we're talking about lost production for one year at this site --

MR. DENNING: So, this --

MEMBER RAY: -- at a site, I should say.

MR. DENNING: This --

MEMBER RAY: And we don't consider lost production countrywide or something like that --

MR. DENNING: No.

MEMBER RAY: -- because --

MR. DENNING: Yes.

MEMBER RAY: -- there is the theory that, well, that loss production creates economic benefits -- we'll give you more time -- and that whole debate about whether that's a cost or not because of the offsetting benefits of recreating new generation to replace it, or whatever aren't included. And I only want to make that point because, like I said, it pales in comparison to the apartments and stuff we're talking about within the scope of this discussion.

MR. DENNING: Yes, you're saying with that -- let me see if I understand. So you're saying that if you look at apartment buildings and say I'm going to have people that are not going to be in those apartment buildings for years -- yes, that --

MEMBER RAY: But the lost production on

a cost basis is huge by comparison with what we're talking about, what we were talking about.

MR. DENNING: The one-year loss.

MEMBER RAY: Yes, sir.

MR. DENNING: So using the multiple year loss or you're --

(Simultaneous speaking)

MEMBER RAY: Yes. Yes, just take Japan as an example --

MR. DENNING: Yes.

MEMBER RAY: -- where the cost to society is far beyond the cost to the region where Fukushima is located, the consequence of the accident.

MR. DENNING: So with regards to loss of power, that's true. With regards to relocation of people in terms of -- those people are probably all largely -- the workers are probably working somewhere else now. They're probably working some place else.

MEMBER RAY: I'm talking about the first thing you said, which is the loss of production, the impact on the economy of the lost value in the investment already made in the production facilities that are no longer operating.

That is an enormous impact.

MR. DENNING: I think it ought to be looked at seriously, much more seriously than I did. And that's part of why I didn't get into the multi-year effects was that you do have this complication of this resilience factor --

(Simultaneous speaking)

MEMBER RAY: I understand that totally, but to most people when you're talking about a cost, it is lost value that exists otherwise, not stimulated resilience in an economic sense that has to be considered. But you're merely -- you've invested in something that no longer has value, and that's a cost?

MR. DENNING: Yes.

MEMBER RAY: Okay.

MR. DENNING: There's --

(Simultaneous speaking)

MEMBER RAY: I didn't want to debate it. I just wanted to be clear that that --

MR. DENNING: It's not --

(Simultaneous speaking)

MEMBER RAY: -- in fact by comparison with what we were talking about is much greater.

MR. DENNING: Well, that may or may not

be true.

MEMBER RAY: Well, that was my assertion.

MR. DENNING: Yes.

MEMBER CORRADINI: So --

MR. DENNING: Yes?

MEMBER CORRADINI: -- can you go back?

MR. DENNING: I can always go back.

MEMBER CORRADINI: I'm still diddling with the green and the purple.

MR. DENNING: Yes, yes, yes.

MEMBER CORRADINI: So --

MR. DENNING: This happened to be low contamination.

CHAIRMAN STETKAR: Go to --

MEMBER CORRADINI: Any one of those.

CHAIRMAN STETKAR: -- the green. It's easier.

MR. DENNING: I'll go to the green.

MEMBER CORRADINI: So in this one there's no decontamination offsite. There is decontamination onsite.

MR. DENNING: Yes.

MEMBER CORRADINI: You didn't include the cost that Harold was asking about.

MR. DENNING: The multi-year -- the loss of ability to use -- it may be production facilities or land --

MEMBER CORRADINI: Yes.

MR. DENNING: -- in years beyond the year in which you --

MEMBER CORRADINI: Okay.

MR. DENNING: -- have lost production.

MEMBER CORRADINI: So if I were to say that I wanted to use this as a -- if I were to want to us this as societal risk, besides the arguments about money, which we'll eventually come to, why is it 100 plants and not a plant? You're looking at a plant site. Now you're multiplying by 100.

MR. DENNING: Because it's a --

MEMBER CORRADINI: I'm still struggling.

MR. DENNING: So this is a societal risk where we're trying to see what's -- so we're asking the question is it okay to operate nuclear power plants in the United States?

MEMBER CORRADINI: So we don't do this for fatalities, do we? I mean, I didn't do SOARCA, do the calculation for SOARCA on the QHO-1 and QHO-2 and then multiply by 100.

MR. DENNING: Yes, so when the NRC developed the safety goals, the stated purpose was to determine are we doing an adequate job of protecting the public against nuclear power plant accidents? And when we talk about in saying things like Chernobyl or Fukushima would have satisfied that, we looked to see what -- how different plants are in NUREG-1150. And we use safety goals in the sense through the LERF and CDF, but other than that we don't ask these bigger global questions.

MEMBER CORRADINI: Okay. But I'm --

MR. DENNING: Yes.

MEMBER CORRADINI: -- I understand what you just said to me, but I'm trying to figure out if I were to buy into your risk model, how would I use it? And what you're telling me is the societal risk, if I wanted to look at a plant, I need to divide that societal risk by the current population of plants, the dash line. In other words --

MR. DENNING: No. Yes, so you could look locally at the societal risk for a plant. And I mean, what -- I'm sorry, you could absolutely do that for a plant in the same way in NUREG-1150 we did it for plants, yes. You could do that.

MEMBER CORRADINI: All right. I think

I understand. I'll hold off.

MR. DENNING: So I --

CHAIRMAN STETKAR: So for this baseline --

MR. DENNING: -- no, I said -- I answered it poorly. You're right, we could have looked at a single plant and just -- because in fact that's what we did, right? I looked at four plant sites.

MEMBER CORRADINI: Unnamed?

MR. DENNING: Unnamed.

MEMBER CORRADINI: Which of the four is this the green curve? I forgot to ask that.

MR. DENNING: That's average. That's average. So that was just -- I took a strict average across the four of them, although that may or may not be --

(Simultaneous speaking)

CHAIRMAN STETKAR: Yes, he distributed the plants. Twenty-five percent --

MR. DENNING: Twenty-five percent equally, yes.

CHAIRMAN STETKAR: -- were attributed to each of those four.

MR. DENNING: Yes.

MEMBER CORRADINI: Okay.

MEMBER BLEY: And you could do what you're saying, but that societal risk baseline, the blue dash curve comes from across the whole country, from all of these major events that we've seen?

MR. DENNING: That's true.

MEMBER BLEY: It's not a local --

MR. DENNING: That's true.

MEMBER BLEY: -- result?

MR. DENNING: That's true.

MEMBER BLEY: It's an average for the country.

CHAIRMAN STETKAR: It's Katrina plus in principle --

MR. DENNING: That's true.

CHAIRMAN STETKAR: -- a massive earthquake in California, if it ever happens.

MEMBER BLEY: Well, in that score --

MEMBER CORRADINI: But if I just may finish my droning. So the moment I start doing this all I see is massive argument and uncertainty about the blue dash curve, as to whether it's local or national, what I put in, what I put out, how I count the dollars. I mean, I understand where you're going. I just think the uncertainty and the argument generated will be insurmountable.

MR. DENNING: So, yes. And so that's the question is is it our intent to have a QHO there, or a QSO that relates to the overall population, the overall societal risk, or do we want measures that are applicable to a particular plant?

MEMBER CORRADINI: Okay.

MR. DENNING: Okay? So when we get to measures, then that is a different story of what could be applicable to a specific plant --

MEMBER CORRADINI: And then --

MR. DENNING: -- just like we use CDF on LERF for specific plants.

MEMBER CORRADINI: Okay. That's just a comment you can ignore. Can you go to the purple one --

MR. DENNING: Yes.

MEMBER CORRADINI: -- which includes decontamination cost?

MR. DENNING: Yes.

MEMBER CORRADINI: So this is based on bids in Japan?

MR. DENNING: Yes.

MEMBER CORRADINI: So to what level of decontamination is it being assumed?

MR. DENNING: That's taking it down to the level at which you can repopulate. And I --

MEMBER CORRADINI: About a half a rem per year?

MR. DENNING: That's probably half a rem, yes.

MEMBER CORRADINI: Okay.

MR. DENNING: Yes.

MEMBER CORRADINI: Okay. All right. Thank you.

MR. DENNING: Okay. So I wanted to show the difference with mean risks to give you some feeling for this. So if you look at the base case, then that mean risk is 10 million to 3.3 times 10 to the 8th dollars per year, but recognize that if you look at the U.S. population, that's a dollar per person on the high side. It's not a very big societal risk. And indeed, if you look at the societal risk to the population from the curve that I showed, that's not really a huge cost either.

I looked to see -- because I was also getting over this question of the benefits and what

-- so what's this -- I don't want to get into cost benefit tradeoff, because I think what we're looking right now is acceptable risk. But on the cost benefit side recognizing some 0.1 does ask the question there, then the question is how big are the benefits of nuclear power? And I think that they are massively bigger than what you might think if you looked at the value for electricity production. And we can talk about that later.

Because that bottom paragraph is the thing that drives my life right now, which is this looking at this future of global warming, major freshwater crises, loss of arable land. And what I think is the biggest societal problem that we face, which is replacement of fossil fuels, not from the global warming side of it, but just that we're going to consume all the fossil fuels that are extractable in to me what's a short period of time, because I'm 75 years old. So I have different perspective than most people.

But when I look at my grandchildren who could live 100 years from now and I ask myself is there going to be a fossil fuel crisis some time in their life that's just monstrous? I think there is. And I think that when we get to asking these questions of looking at societal risks and benefits, that there's a huge future need. And I'm getting ahead of something I'm going to say later this afternoon, so I'll stop.

MEMBER SCHULTZ: Rich, before you -- I don't know if you're going to -- is that your last slide?

MR. DENNING: That's it. Yes, it is.

MEMBER SCHULTZ: Oh, good.

(Laughter)

MEMBER SCHULTZ: Then you aren't going to --

(Simultaneous speaking)

MEMBER SCHULTZ: Wait a minute.

MR. DENNING: I'm sorry to tell you that --

MEMBER SCHULTZ: Taken out of context.

(Simultaneous speaking)

MR. DENNING: -- this afternoon.

MEMBER SCHULTZ: Taken out of context. The one bullet I don't understand with regard to this slide is the second one, on a per capita basis these values represent --

MR. DENNING: Okay.

MEMBER SCHULTZ: -- a small risk,

because --

MR. DENNING: Yes.

MEMBER SCHULTZ: -- I thought we were looking societal and global and --

MR. DENNING: Yes.

MEMBER SCHULTZ: -- across --

MR. DENNING: So that was my -- so look at the base case, 3.3 times 10 to the 8th dollars per year.

MEMBER SCHULTZ: Yes.

MR. DENNING: And you look at population in the United States. On a per capita basis, that's a dollar per person per year.

MEMBER SCHULTZ: But I'd like to --

MR. DENNING: That's -- I'd like to throw mine on the table right now. That was the sense in which I meant it.

MEMBER SCHULTZ: Okay.

MR. DENNING: But if you're Belgium and you ask the question can I afford to have even a risk that's low like that recognizing that I might have to evacuate my entire country. I may not be able to live in my country. And you know, when France asks the question what if I love my vineyards, I mean --

(Laughter)

MR. DENNING: And honestly, ISRN --

MEMBER SCHULTZ: We all ask that question.

MR. DENNING: -- has done this big consequence study. They didn't put it in a risk perspective, but they've done the consequences and their evaluation is huge relative to the land evaluation that I used here, but partly it's what if I lose my vineyards?

MEMBER SCHULTZ: Okay.

MR. DENNING: But I think it's a real question that it's an existential question for Belgium. Should I have nuclear power, because if I have that accident, I've lost my country. In the United States we have that accident, even though it could be a huge land area, we've got a lot of land.

Okay. I think that -- I'm not sure. Is my time gone?

CHAIRMAN STETKAR: Don't worry about time. We're okay. Any other questions for Rich?

MEMBER RAY: There is just one.

CHAIRMAN STETKAR: Push your button.

MEMBER RAY: There is, thank you, just one, but it's more of a note. I'm struggling with contrasting earthquakes and tornadoes. Not contrasting them, but using them as references for risk. I understand they are a risk. I understand that we need some reference. But nevertheless they are not avoidable in the same way that siting a power plant is a discretion.

MR. DENNING: But in some sense I agree to some extent they're not, but to some extent they are. Look at Katrina and the question was should we have built a better dike system, should we have invested that to offset that, right? I heard the other thing that there's some benefits that come from all this. I think from the other side it's the other way around. And I think that there is -- if we look at epidemics, for example, I think that there is a really great analogy here that we have to recognize. You look at Ebola and what happen in the United States. So we had this tremendous concern in the United States. Individuals were scared to death they were going to die of Ebola. And every expert that went on television said we know that because it has low transmission that we can control Ebola in the United States. We are not going to have an Ebola epidemic in the United States.

And I've done a fair amount of work on the risk of biological weapons. So we know that we can model that and we know that that was always controllable. So the worst thing that we could have done was to have people from the United States, medical people that were risking their lives going to Africa and stopping it there. Worst thing we could have done was to discourage them from going. So what did we do? We say, okay, if you go, when you come back, you've got to stay a month in isolation or something like that. So we did the worst thing.

What we didn't recognize -- and the other thing we should have recognized is that we have very few facilities in the United States that are able of handling an epidemic. Very few facilities. That was obvious. Just a handful of facilities. The risk of a major epidemic is real. I mean, it's a major risk. And we saw this risk there, but it's a major risk. It's just a matter of time and in a sense we're forcing these little -- these guys to get better and better at avoiding our antibiotics and stuff like that. We also have people in laboratories that are developing things that are both super-infectious and super lethal, and they can get out and stuff.

So what we should have learned from that was we have to invest more in those facilities because we're going to have an epidemic and we're not going to be able to do that. And so what's happening now? Nothing. So I think there's a close analogy here with those things and the recognition that it doesn't -- I'm sorry. Yes?

MEMBER REMPE: I guess I have another question or comment, too, to further muddy the water. Do you ever think about personal choice? I took a plane yesterday from Idaho because I didn't feel like driving across the country. And so some of the people --

MR. DENNING: And you were safer than driving across the country.

MEMBER REMPE: Yes, well, there are some things about people living near plants and because of personal choice. And so when you start talking about societal risk, sometimes the folks most affected were the ones who made a choice.

MR. DENNING: Yes. Yes, but I think there's another side of here. Half of this story is that the reality is that you can talk to somebody that lives right next to a nuclear power plant and say you should never worry a day in your life about the fact that you live there. That risk is so small relative to other things.

Now if the warning goes off and they tell you to move, move. But there's no reason, there's no logical reason why you shouldn't live right next to that plant.

MEMBER REMPE: I agree with you, and I might do that, too, but then of course then --

MR. DENNING: Sure.

MEMBER REMPE: -- okay, other folks might -- there is personal choice on some risks that people take. And when you talk about societal risk, I think how does one accommodate that type of consideration?

MR. DENNING: Yes, I'm not sure how you do it and I'm not sure that --

MEMBER REMPE: Because there's a control boundary of who you include and, okay, the government might decide we need power and we will make that choice. We're going to do this.

MR. DENNING: Yes.

MEMBER REMPE: And so there's personal choice in there, too. And I just find it very complicated to try and come up with having to address this.

MR. DENNING: Yes. Yes. Yes.

MEMBER CORRADINI: So I'm still back with your purple curve. You don't have to show it.

MR. DENNING: Yes.

MEMBER CORRADINI: So if underneath all of this there is a decontamination limit that I have to get to, that's a health-based number. So is 0.5 rem defendable as a health-based number to decontaminate to so that the population can return, or is it 1 rem, or is it 2 rem, or does that have a big effect on cost?

MR. DENNING: Yes, so it certainly has some effect on cost. There's no question about that. As far as this question of -- so at Fukushima people didn't just relocate at two rem. Everybody that was at one rem also did by personal choice.

MEMBER CORRADINI: Right, but what I'm trying to get to is --

(Simultaneous speaking)

MR. DENNING: So if you raise it up the other way, if you increase the pegs, then --

MEMBER CORRADINI: Sample?

MR. DENNING: Yes, for example. Then -- so I think that's going to be a hard sell to raise the pegs.

MEMBER CORRADINI: Should the be lowered? I mean, maybe I'm on the other side of this and half a rem is way too liberal. Should they be lowered? Or is it just a hard sell period, so don't go there?

MR. DENNING: Well, no, I think it's a good question. I think it's one that we really have to get to this linear no-threshold and better understand it in the future to be able to address some of those things, because you know we double the population -- the population exposure is double the natural background due to health-related exposures. And we suspect that that's a good thing, that we save a lot more lives, and we don't.

MEMBER CORRADINI: But, so let me try another one on you and then I'll stop --

MR. DENNING: Yes.

MEMBER CORRADINI: -- which is if I have a set of pegs which are politically hard to change, there's a cost due to evacuation, which are deaths. I think Dennis -- somebody over here asked it. It seems to me there's a minimum in this, which is there's a set of pegs where I move some set of people where I actually don't incur a lot of death. Or to put it another way, if I plot a curve of relocation versus fatalities, I'm back to health. I'm trying to avoid dollars. If I have relocation versus some sort of fatalities, latent fatalities, there's an equivalent curve that goes the other way. If I allow for or take account of essentially deaths due to relocation because of evacuation, there's a minimum somewhere.

MR. DENNING: Yes.

MEMBER CORRADINI: And isn't that from a protective action guideline standpoint something to at least look at?

MR. DENNING: Yes, it is something to look at, but I think -- and I think the other thing we really have to seriously look at is the logic of evacuation versus relocation, particularly when we get this afternoon and to -- if we look at external events and stuff like that, I think particularly for those events you have to really go back and ask yourselves are we just too concerned towards LERF, towards --

MEMBER CORRADINI: Okay. I see your point.

MEMBER SCHULTZ: But more of what we talk about is certainly affected by what our understanding and belief is with regard to the actual effects of radiation on health.

MR. DENNING: Yes, absolutely.

MEMBER SCHULTZ: And we talked about it in the beginning about the effect on the individual. And my view is that it's really important that we get a better understanding associated with a linear threshold experience and what has been learned from Fukushima in that area to get the right approach to relocation and evacuation.

MR. DENNING: I don't think --

(Simultaneous speaking)

MEMBER SCHULTZ: And then eventually it will affect the societal discussion, too.

MR. DENNING: Yes. So I don't think we're going to learn anything about LNT from Fukushima. We're never going to see any epidemiological evidence within the Fukushima population. We'll look for 100 years and we're never going to see anything. We're never going to see any statistics that are outside of -- yes.

MEMBER SCHULTZ: Doesn't that tell you

something?

MR. DENNING: No, it's just --

MEMBER SCHULTZ: I mean, I understand it's --

MR. DENNING: Yes.

MEMBER SCHULTZ: -- that's the difficulty we face --

MR. DENNING: Yes.

MEMBER SCHULTZ: -- but we are using the lack of information -- you're saying there will be a lack of information, which does in fact tell us something, and yet we are not changing the way we look at health effects of radiation.

MR. DENNING: But I think that Fukushima isn't -- I just -- it's not going to give us much additional knowledge, because I think we already -- I mean, I could always be totally wrong. Maybe we're going to see something there and that's why you look, but I just don't think that -- the evidence is that you just never can see anything. Because we do have a good idea of what the population did receive and will receive. And it's low.

MEMBER SCHULTZ: So you won't see it, but that's contrary to what we're assuming in the analyses we do where we assume that there is no threshold.

MR. DENNING: Right. Right, although I'm not sure we're going to use that for anything other than -- I mean, certainly that's some of the logic behind the pegs is assumption of avoidance of consequences when indeed there may not even be any consequences.

MEMBER SCHULTZ: Right.

CHAIRMAN STETKAR: At this point I do need to worry a bit about the time, and I think we're going to probably continue this same discussion when we have the next presentation --

MR. DENNING: Yes.

CHAIRMAN STETKAR: -- if I'm not incorrect about that. So is there anything more for Rich?

(No audible response)

CHAIRMAN STETKAR: If not, before we break apparently someone out on the bridge line has not muted their phone, because we've received reports that there's rather loud music playing in the background and it's disrupting other people's ability to hear our proceedings. So could everyone on the bridge line make sure that you mute your phone so that we don't have that cross-contamination of the audio? We can't do it from here. You have to do it individually. Press star, six on your phone. That will mute the outgoing. If you want to make a comment later when we open the phone line, you can press star, six again. So I'd implore everyone out there listening in to please mute your phones because it will help everyone hear our proceedings a little bit better.

And with that, we will take a break and reconvene at 10:45.

(Whereupon, the above-entitled matter went off the record at 10:30 a.m. and resumed at 10:45 a.m.)

CHAIRMAN STETKAR: We are back in session. A little late, but we're back in session. And we'll now hear from the good Professor Vicki Bier --

MS. BIER: Okay.

CHAIRMAN STETKAR: -- as opposed to the bad Professor Vicki Bier. I've heard stories about the bad one.

MS. BIER: Okay. First of all, thank you for the opportunity for being here. The work that I'm going to be describing was funded by Idaho

National Lab but, of course, does not reflect the opinions of Idaho National Lab, if the lab has opinions.

So some of this at the intro is going to be a little bit repetitive with what you already heard this morning. The existing NRC safety goals, first of all, have long been recognized as being narrowly scoped. First of all, as I think, I forget whether Rich or Vinod pointed out that they focus on dose to individuals because even this supposed societal safety goal is normalized by a population. So they don't truly constrain large societal impact. In fact, a colleague of mine years ago wrote a study showing that you could cite a nuclear power plant in downtown Manhattan and still meet the societal risk goal because you just normalize by a bigger population. And it doesn't explicitly address kind of the other aspects of societal risk and societal disruption that Rich was talking about.

And as we've seen in Fukushima, there are social or societal determinants of health, such as stress-induced fatalities. I think we have to be a little careful about saying that a death is a death because in the kind of TMI days people thought that the risk of evacuation was mainly a risk of car accidents. What we found out in both Katrina and Fukushima is that the risk of evacuation is mainly a risk to people who are already medically frail or fragile or vulnerable: the elderly, chronically ill, infants, people with severe health conditions, etcetera.

It's also difficult to count because when a sick old person dies, for example, in Japan, there's currently a procedure to get that registered as a Fukushima-related death, but it's probably a very difficult thing to ascertain.

Anyway, focusing on the societal risk, the 0.1 percent of cancer fatality risks, that part of the goal is normalized by population, so it does not constrain the total impact of an accident.

So our objective when we started this about three years ago was to find a way to evaluate societal disruption as a basis for developing what might be either a revised societal risk goal, which is kind of where we first started out, or possibly, you know, revised screening procedures, etcetera. And we were looking both at health effect but also, in principle, non-health concerns like property damage and land interdiction. Barb, I know, was pushing us early on to do more on land interdiction. I think that's complicated for some of the reasons that were discussed that, you know, whether you interdict farm land or urban land can have a very big difference.

But some of the gaps left by the current focus on just radiological risks to health include not only the health risks due to evacuation and the cost of the decontamination but also loss of communities, loss of income in various industries, need for replacement power. And there are psychological issues. In the case of Chernobyl, it was labeled as relocation trauma, but I think in Japan also you're seeing accounts of depression or suicide, etcetera, related to the relocation. And I think certainly the experience in Japan has shown that the societal disruption can be at least as important as the radiological health risks.

And in our study, we converged fairly early on on number of people relocated as a proxy for the level of societal disruption. You could do, you know, much more elaborate models, but number of people relocated has the advantages that it's easy to compute or straightforward to compute and not terribly controversial. You can specify what the guideline is and get a number out.

So we did an analysis in a way similar to what Rich did. We picked five reactors. Again, I won't say where they are, but they were chosen not so much to be representative as to span a range both in terms of geography and in terms of population density, some high density and some low density, and we specifically did not include what one might guess would be the worst-case plant.

We did four unmitigated accident scenarios out of SOARCA kind of to the best of our ability to approximate SOARCA's source terms. So long-term station blackout; short-term station blackout without DC batteries, which is, therefore, actually, more severe than long-term blackout; tube rupture for PWR and long-term station blackout without RCIC for BWRs.

We did not consider interfacing system LOCAs deliberately, partially because it is low probability but also because there is at least a concern there about early health effects and we wanted to focus only on long-term health effects, so we chose not to look at that.

CHAIRMAN STETKAR: But Rich and company

explicitly did include containment bypass interfacing system LOCA. Again, I didn't get a chance to ask them. My sense is it was driving the right-hand tail of his risk curve because it's the low-frequency large releases that would result in more contamination and, you know, larger decontamination costs, more population relocated.

MS. BIER: I think what you will find for us is that what drives the tail-end of our curve is weather.

CHAIRMAN STETKAR: Yes, well, your analysis is different.

MS. BIER: Exactly.

CHAIRMAN STETKAR: One question I had, and I have a question out to someone who can't participate in this discussion who's doing some research even as we speak, you've characterized Fukushima as a long-term station blackout in your paper. There's a sentence I can read from it.

MS. BIER: Okay. I would have to go back and review that.

CHAIRMAN STETKAR: And so I was kind of comparing source terms for long-term versus short-term station blackout in your paper and trying to think of what the implications are because the cited releases from Fukushima are much larger than the long-term station blackout releases that you use in your paper.

MS. BIER: Okay. I do not recall the sentence about Fukushima. I would have to go back and look into it. But that sentence, I think, is not important to our conclusions. The conclusions were driven by this analysis, not by --

CHAIRMAN STETKAR: I was just trying to understand, though, because you do this for a variety of scenarios that are -- I'm not sure how you, well, you didn't consider frequency.

MS. BIER: Correct. It's all conditional on the --

CHAIRMAN STETKAR: Okay. So --

MS. BIER: -- scenario.

CHAIRMAN STETKAR: Okay.

MS. BIER: All right.

CHAIRMAN STETKAR: Thanks.

MS. BIER: We looked at actual weather that was in effect on each of 24 different dates. They weren't quite randomly chosen because we tried to make sure that we got a variety of weather and, you know, some snow days and some not snow and so forth. But this was chosen, you know, we chose a day in the middle of each month, and Greg Hammond who collected this data would, like, set his alarm to wake up at two in the morning if randomly that scenario was predicted to start at two in the morning to collect the weather data. And we didn't have access to the actual on-site weather, but we got the nearest weather service station, so pretty close to the actual on-site weather. And we did not just the weather at the moment of release, but I think the next 24 hours maybe, something like that, so we'd be --

CHAIRMAN STETKAR: That's what I was going to ask. You did take a 24-hour --

MS. BIER: Right. So we got all the changes in one direction that actually happened in those 24 hours.

CHAIRMAN STETKAR: Thank you.

MS. BIER: We used RASCAL for dispersion modeling. We did a pretty detailed comparison of RASCAL to HYSPLIT and found that they were pretty similar, that the 2D and 3D didn't seem to make an enormous amount of difference, at least for the purposes that we were using it for. As I said, we tried to match the source terms for SOARCA, but it's difficult to do that in RASCAL exactly, and so our source terms are close-ish. I wouldn't want to say, you know, they are really super close matches to the SOARCA source term, but they were our best attempt to match the SOARCA source terms. And we looked subsequently at doing it with the pre-HYSPLIT version of MACCS. Again, we found some pluses and minuses of the two models, not a clear winner of which one seemed better or more reliable.

So the RASCAL dispersion model gave -- so this, I think, is the Fukushima comparison and indicated that at Fukushima it gave an overestimate of dose in some areas, which seemed reasonable because it's supposedly a conservative code. Kind of a cartoon version of what we did is RASCAL generates doses or concentrations in little tiny geographic sectors. So in this picture, the red sectors are the ones where the dose exceeds the 2-rem guideline. I think we did go out actually past 25 miles but not past 50, as Rich talks about. Maybe the reason we didn't need to go past 50 is because we didn't do containment bypass.

So these are kind of one significant figure summaries of the number of people who would need to be relocated at a 2-rem protective action guideline at each of these sites. So why are there confidence intervals? Well, because we had 24 different weather scenarios, which create high and low numbers of relocation, depending which way the wind is blowing.

And so as you can see in plants D and E that are low-populated sites, it's really hard to get a scenario where you have to move more than a few tens of thousands of people. On the other hand, plant A, to an order of magnitude, you can evacuate over a million people, and we'll see more detail on that in a moment.

This is an analysis of -- let me go back for a minute. There we go. The next picture is, you can think of as a blow-up of the upper right-hand steam generator tube rupture cell in this table. So while the confidence intervals are, roughly, between 300,000 and a million, if you actually plot a histogram of the 24 different weather conditions, you can see that 25 percent of the relocations involve more than a million people and up to about 1.5 million, which is on the scale of what happened at Katrina.

CHAIRMAN STETKAR: Vicki, you're going to hear this more from me, but I might as well start asking now. Do you have any sense of what the frequency of that short-term station blackout with induced tube rupture release would be?

MS. BIER: Well, we used, we would use the number from SOARCA for frequency, and it's pretty small.

CHAIRMAN STETKAR: Okay.

MS. BIER: I don't remember how small. I think it's in the paper. If not, I can get it for you.

CHAIRMAN STETKAR: I don't think it is in the paper. I couldn't find it.

MS. BIER: But in other work that we are currently doing with one of the authors here, we are using the SOARCA frequencies. So I have no personal basis to know how high or low that frequency would be, but that's the number I --

CHAIRMAN STETKAR: Actually, I think it is in the paper. It's about somewhere between about 1 and 8 times 10 to the minus 7 per year, if I back out the numbers.

MS. BIER: Okay. So unlikely but in the realm of the feasible. So this is another plot of basically the data in this picture, and what it shows is that these CDFs don't necessarily have that nice knee in the curve where they suddenly go down steeply, that basically the only thing that is driving high or low consequences in this scenario is which way the wind is blowing and is it blowing in the direction of a populated area or not, and that's not vanishingly rare to get a bad wind day.

CHAIRMAN STETKAR: Just for the sake of those of us who can't really read the Y axis values because there don't seem to be any, what are those values? Since this is a --

MS. BIER: So, I mean, this was plotted conditional on this happening, so you could think of that top as being one, but you could also plug in your number from the SOARCA frequency at the top of 10 minus 7 or whatever it was and --

CHAIRMAN STETKAR: You have horizontal lines going across there, so it must be increments of something. Factors of ten of what?

MS. BIER: No, the Y axis is frequency, and I think the Y axis is not on the log scale. So I would have to confirm this. But if you have a one at the top, then I think it's like, you know, 0.8, 0.6, 0.4 or --

CHAIRMAN STETKAR: Well, is it only the conditional fraction of each weather condition? I don't get it. Honestly, I don't get this curve.

MEMBER SCHULTZ: Perhaps, can we go back to the bar graph?

CHAIRMAN STETKAR: If this curve is derived from the histogram you showed on the previous slide, then it might somehow be fractions of the 24 data points for weather conditions.

MS. BIER: Right. You have 24 points on the curve. I just kind of visually scanned and confirmed, and so, yes, if you go down a point, it's like 1/24th each time you take a step.

CHAIRMAN STETKAR: But it's only weather conditions. I mean, this whole thing --

MS. BIER: Right. It is only showing --

CHAIRMAN STETKAR: -- multiply it by a frequency but it's --

MS. BIER: Exactly. But it's showing the uncertainty due to weather conditions. But when the only thing you need to have a really bad outcome is the wind blowing in the wrong direction, it's not the kind of thing we're used to where you need six or eight bad things to happen. The six or eight bad things have already happened before you got here, and now the only difference of is it good or bad is which way the --

CHAIRMAN STETKAR: I just wanted to make sure we understood what --

MS. BIER: No, I appreciate it.

CHAIRMAN STETKAR: -- this is showing us.

MS. BIER: Yes, okay. So the numbers on the previous slide are certainly not out of the realm of the feasible compared to Japan. I just recently went back and tried to reconstruct what we do know about how many people were evacuated or relocated in Japan, and it turns out the numbers actually vary quite a bit depending which source you use and etcetera. You can find numbers between about 100,000 up to about 500,000 that were relocated. Japan Reconstruction Agency has on their website a number of 470,000 some place, and I don't know if that includes voluntary relocations, if it includes people who relocated due to tsunami damage and not due to radiation. I don't read Japanese, so I can only understand what's in the English translations. But there are some very high numbers out there.

We had started with a number that comes close to 500 with the PDM when we went back to reconstruct. There are other sources that give that number, but I don't know how reliable it is.

Same thing for fatalities due to stress. There are numbers that get up close to 3,000, but some of those may be exaggerated. I don't know that I would want to put a lot of credibility on these at 3,000 or 700 or whatever but, certainly, a significant impact.

And, of course, the results in Japan could have been much worse than they were because the wind was, for most of the time, blowing out to sea. So the fact that you could get us an area where you might have to relocate 1.5 million if the wind was blowing in a worse direction does not seem implausible.

The return to normal also is not necessarily rapid. Most natural disasters return to normal a little faster. Experience in both Japan and Chernobyl is that the relocations can be quite long, and the RASCAL software only does, like, one year, two years, and 50 years, I think. So this shows the ratio of how many people would need to be relocated to meet the 50-year guideline compared to the one-year guideline, I think. And I would just note that meeting the 50-year guideline might require relocating more people in some of the 24 weather scenarios. It doesn't mean they have to be relocated for 50 years. Probably at some point, five years, seven years, ten years, things go down enough that they can come back. We just haven't redone the analysis using MACCS or whatever to show at what point that happens. We actually wanted to do that this fall, and there was a glitch and somebody didn't approve the MACCS distribution, so we never got the code in time to do it.

So this shows a quick comparison. I think this is four different weather days of that steam generator tube rupture. And for each curve, you can see, okay, the middle point is the number of people relocated, and I think estimated cancer fatality on the X axis for 2-rem. If you go up to 4-rem, you get a little more cancer and a little less relocation, etcetera. So this just shows kind of a visual of what would happen if you changed protective action guidelines.

Quick questions? Okay.

So as you can see from the increasing the protective action threshold above 2-rem, you would reduce the number of people you have to relocate. You would somewhat increase the number of latent cancers but not enormously.

At the current threshold of about 2-rem, preventing one cancer fatality requires relocating on the order of 800 to 1,000 people. That's not obviously a bad number. It's kind of in the range where it's hard to think about. If relocating one cancer fatality required relocating 20 people, we'd say, oh, of course we want to do it. If it was, you know, a million people, we would say, oh, that's crazy. This is about at the point where it's difficult to think about, which I guess means it's not obviously a bad threshold to have. But if we think that linear no-threshold is overestimating the fatalities, then, in reality, we are relocating a lot more than 800 people to prevent one cancer.

CHAIRMAN STETKAR: Vicki, as I read the paper, maybe you can help me. There was a paragraph in the results section that essentially expounds on this slide, and it seemed to be telling me, it says "note also that the LCF, latent cancer fatality, numbers were computed using a linear no-threshold assumption, which can be controversial at low doses since many people at low doses may face little to no risk. Therefore, the number of people that would need to be relocated to prevent one cancer fatality could, in fact, be even higher than the estimate of 800 indicated here." That bothered me because if nobody ever got a cancer, regardless of whatever the dose was, we wouldn't have to relocate anybody. So I don't understand, I don't understand the implication that we might have to relocate even more. It seems backwards.

MS. BIER: I'm not saying what if this went to zero cancer risk. What I'm saying is let's relocate 800 people. Linear no-threshold says that saves one life.

CHAIRMAN STETKAR: Right.

MS. BIER: In reality, maybe that saves only half a life in expected value if the risk is smaller than we think it is. That means that if 800 people is saving only half a life statistically, then we need 1600 to save one life.

CHAIRMAN STETKAR: I understand how you're doing the math. I don't think it makes any sense. Suppose if I got 3,000 rem, I had zero chance of dying, I don't need to move.

MS. BIER: Right, correct.

CHAIRMAN STETKAR: So I don't save anybody by relocating everybody because if everybody gets 3,000 R, nobody dies.

MS. BIER: So I think we are actually in agreement, which is this slide is another way of saying if we don't believe linear no-threshold, then we have kind of a wasteful process. And I think we're in agreement on that.

MEMBER BLEY: And the second bullet is confusing in that it's anchored to one cancer.

CHAIRMAN STETKAR: That's right. And --

MEMBER BLEY: Well, no, they sound the same to me.

CHAIRMAN STETKAR: Well, yes, but, I mean, the statement in the paper is more explicit than the bullet even. It says if we don't believe linear no-threshold, we may have to evacuate more people.

MS. BIER: Right. Potentially, an infinite number if the risk is zero, right? So I don't think we're in disagreement on the implications. Maybe it could have been worded better.

CHAIRMAN STETKAR: I think it could have been worded better. I see how people do a math by dividing X by N.

MS. BIER: Yes. Anyway, the other point that I do want to make here is that if we relax the protective action guidelines, the benefits in terms of reduced disruption happen immediately. The cancer fatalities that could conceivably be increased by doing that, even if they occur, they will not occur for many years, on average. So we're trading off, you know, an immediate cost for a possible eventual benefit.

Overall, first of all, we came out to say that, you know, number of people relocated we think is a reasonable proxy for overall disruption. It's relatively objective to calculate. It is, in a sense, health-based because we have seen that big relocations kill people. And I think it would not be inordinately controversial to decide to include that in a goal in some way.

I think the observation in current practice that Vinod mentioned this morning that we evacuate everybody first and then count up how much dose is left among the people who didn't evacuate, you could put almost any cancer fatality risk goal you could imagine and just say that you would evacuate enough people to meet that goal, and it doesn't seem like a very reasonable way of assuring safety and also puts a significant burden on the people who are relocated, whereas most other things we do to improve safety put a burden on the plant owners and operators. So we think it's worth looking at this further.

So one possible safety goal, if one wanted to go that way, would be to compute some type of weighted sum of cancer fatalities and relocation numbers. And, obviously, every person relocated counts much less than one fatality, but we could try to estimate that, for example, based on 2,000 per person rem or 5,000 per person rem, whatever number you guys are going with these days, and some estimate of the cost of relocation.

This type of a goal that constrained both fatality risk and relocations would provide, I think, a better true societal risk goal without encouraging excessive relocation, which the current practice sort of does, and, in theory, could also accomplish some of Rich's goal of providing guidance for signing of advanced reactors and other reactors that people might want to build in the future.

In addition, we have also looked at one feature that I think is important which is that the cost of relocation is probably quite non-linear with the number of people relocated. If you're talking about relocating, say, 10,000 people at a low-populated site, you can do that by bringing in some number of FEMA trailers and declare victory. If you're talking about relocating a million people from a relatively high-density suburban area, for example, that's a lot more than 10,000, than, whatever, 100 times as difficult as relocating 10,000 people. You just get to a point where you sort of exhaust the capacity of society to deal with where to put those people and how to resettle them, etcetera.

I think that same kind of risk aversion for large consequences is not as important on cancer fatalities, first of all because the numbers are probably just not that large. But they are also distributed over space and time 20 years from now in a way where they don't all happen in one community in one year. And so I think the risk aversion for large relocations is real.

If you believe that argument, that would tend to suggest that maybe highly-populated plant sites should have to meet more stringent safety criteria in other respects than plants that are in truly remote areas.

CHAIRMAN STETKAR: Vicki, before you get to the path forward here, I see what you're doing, I see what Rich is doing. You use the term "risk" a lot where, in fact, what you've done has no context of risk. It is strictly conditional consequences. So it has no measure of frequency at all. So, for example, by analogy, should I be building asteroid catchers because I can wipe out society with an asteroid? We accept the risk of an asteroid strike because we accept the fact that the frequency is very small. We accept the risk of living in California because, you know, most people accept the notion that the frequency of an 8.0 magnitude earthquake is reasonably small. So how does your construct here address the real notion of risk in terms of both frequency and consequences?

MS. BIER: Okay. So if we were to do what I'm proposing here with this kind of draft equation, here expected value would have to have frequency in. I don't think it's reasonable to have a bound that doesn't take account of frequency. And we would need to do some thinking which Shuji and I are currently kind of just starting to get towards of, when you put frequency in here, is it low enough that you walk away and say, well, all plants meet any reasonable bound and we don't have a problem or not? We're not quite at the stage of being able to answer that, but, hopefully, several months from now --

CHAIRMAN STETKAR: But don't you need to answer that before you start to pose the notion of what an acceptable goal would be? Because if a goal for meteorite strikes is zero fatalities, then I better doggone well be putting up some meteorite catchers over large-population areas because, eventually, we're going to kill somebody with a meteorite striking Lower Manhattan.

MS. BIER: Yes, yes.

CHAIRMAN STETKAR: I don't know when, but it's eventually going to happen.

MEMBER SCHULTZ: And that's what feeds into your conclusion that additional precautions may be needed at popular sites because if you just make that statement and don't bring in a concept of risk associated with it, then it's just an argument is, well, what is a popular site? Is it 100,000 people or 5,000 people or a million people? So it has to be brought into play.

MS. BIER: I think there's two

different parts to your comment. What is a populace site? I think we can kind of answer almost without regard to how likely it is to happen or not, sites at which you could get relocations on the order of a million people. I think we've seen from Katrina that that is just a big hardship, both locally and nationally, to deal with that.

But the question about do we need to formulate this as a goal or is the frequency so low that all plants would need it anyway, I think that's still an important question and one that we're not quite far enough along yet to be able to comment on. But I agree. I mean, to me, that frequency part is why this says may be needed, right? I don't yet know whether I would argue for doing this or not because I haven't had a chance to follow through all the analysis of, if we put in the SOARCA frequencies, am I alarmed by the number or not? Does that help?

MEMBER SCHULTZ: Yes.

MS. BIER: Okay. So next steps. I think we demonstrated, kind of as expected, that the level of societal disruption from a severe nuclear accident could be large and that our current safety goals don't really reflect that societal disruption. In principle, as I said, we started off thinking about this mainly as a way to develop alternative safety goals, but there are other ways this could be incorporated into regulatory analysis on which Bob Youngblood, one of my co-authors, is probably more knowledgeable than me.

So we're currently working on, you know, does it make sense to formulate this as a safety goal, and we could also look at, if we were going to take this into some other type of regulatory analysis, what kind of screening guidelines, for instance, might we come up with?

So I think I won't do my backup slide, which is technicalities, so I think I'm done.

CHAIRMAN STETKAR: I told you we were not pressed for time.

MS. BIER: I don't know if that's because I'm efficient or not controversial enough or what.

CHAIRMAN STETKAR: Well, from my perspective, the controversy is the lack of any consideration of frequency because, as I said, if you only look at conditional -- regardless of how you measure those conditional consequences and whatever calculus you use to move people around and things like that, without considering frequency, you're really not addressing the notion of societal risk, which, you know, as Joy mentioned, she flew here because she knew somehow in the back of her mind that there was less than about a one chance in three million that her plane would go down in flames, and that was a risk that she would accept. If it was one in two, maybe she would have gotten on Greyhound because, you know, it's only one in ten that she could be infected with something.

MS. BIER: So as I said, we are getting towards that. We've been slower than I would have liked for various reasons, but I hope that a few months from now I would be able to have a better answer to that.

The other thing I wanted to say that explicitly addresses the issue of choice, and we talked about this very briefly over break, right now we are taking away choice after the accident and saying, okay, if you have, you know, if you're in an area that is getting 2-rem, you would just be expected to go someplace else.

One strategy we could take is to say maybe we have a much tighter required evacuation area, that maybe, say, at 4-rem, and in the 2 to 4-rem range, we publish some guidance and say, you know, people can make up your minds. And I think the evidence, for instance, at Love Canal, in general, older retired folks who mostly weren't too concerned about Love Canal, young families with children were very concerned about the risk of Love Canal, and letting people sort themselves out in that way actually, you know, people's intuitions of what to do are pretty biologically well-founded actually.

CHAIRMAN STETKAR: I wanted to let you finish. For those of you out on the bridgeline, we've gotten some feedback that the music is coming on and off. It is either right now on or it was just recently on a couple of minutes ago. So if you're on the bridgeline and you're playing music, either turn your music off or please do whatever it takes to mute your phone. Don't put it on hold. Just mute the phone. *6 will mute your phone or turn your music off, please, because it's disrupting everybody else out there on the bridgeline who's trying to listen to these proceedings. So please do that. Please. Thank you. Sorry, Vicki.

MS. BIER: I'm pretty done, again, if there's no further questions.

CHAIRMAN STETKAR: Yes, I cut Joy off.

MEMBER REMPE: I had started to talk, but it's something I assume we're going to hear from Rich later this afternoon. But in my inexperience with this topic, to me, it looks like it's not a societal risk. What you're doing is combining cost of disruption with health effects on a small part of the society, and I don't quite know how you -- educate me on that. You're shaking your head like you know the answer where I'm struggling.

MS. BIER: Well, I don't think I know the answer. I think I know my answer, and Rich might have a completely different answer. I actually think it makes sense to do it on a regional basis, like major urban areas. For example, if you think about the Christchurch earthquake in New Zealand, that was a very big impact on GDP in New Zealand. It would be a pretty small impact in GDP here, but that's not because it's not a severe event. It's just because we're so much bigger that, again, if you normalize it over the entire U.S., I don't think that is a very great argument. I mean, by those counts, September

11th and Hurricane Katrina also were not huge impacts nationally.

MEMBER REMPE: I'm not the person to discuss this, but I just see the issue then of what Charlie brought back in. If we talk about the benefits and the downsides to the U.S., it's not just a subset of, you know, the benefits and who pays for it and things like that. So it does have a bigger effect, and I don't know the answer, but it's just questions in my mind.

MS. BIER: Yes. Getting back to the benefits question, which is really not related to my talk but just responding to one issue you raised earlier, I think I would have given a different answer than what Rich and Vinod gave on that. We do have benefits of hurricanes. People live on the coast. We could choose not to live on the coast, and then we would have no cost of hurricanes or negligible, but we would lose all the benefits of living on the coast.

MEMBER REMPE: And that's a choice. But in the case of a nuclear power plant, I can have that cost, whereas then you have a choice, I'd like to move near the ocean and things like that. And so those things are going to be hard to reconcile, I think.

MS. BIER: Well, I also think that when you look at really big impacts like the 1.5 million, if you're talking about within two miles of a power plant, small populations, most of those people did choose to live there in some knowledgeable sense of choice, right? You know, they could have bought a house a few miles away, and they either wanted to be near the plant or didn't care about being near the plant.

If you're talking about a 1.5 million person evacuation of a major suburban area, most of those people, I think, never made a conscious choice one way or the other about were they okay living there. They grew up there and lived near where they grew up or they lived within commuting distance of whatever job they got, and I think that argument that they chose to be there, as you affect a larger and larger geographic area, I think is not as compelling to me.

Okay. Well, thank you for the opportunity to be here.

CHAIRMAN STETKAR: Dr. Ballinger, you can turn your mike on.

MEMBER BALLINGER: Back on slide number

17.

MS. BIER: I guess I can't see the slide numbers. Okay, here we go.

MEMBER BALLINGER: Okay. I did not read the paper, unlike John, but when I look at these numbers, I instantly ask myself the question, if you put error bars on these numbers, is there a difference between the green, purple, and blue?

MS. BIER: Oh, the green, purple, and blue I'm not arguing are necessarily meaningfully different because they are three different weather days that might have happened to be very similar weather, actually.

CHAIRMAN STETKAR: Those are just four snapshots, right, out of your 24 weather --

MS. BIER: Right. So the interesting question. Well, I don't know. John had so many questions, maybe I'm glad you didn't read the paper. So an interesting question is the high part of the green curve meaningfully different from the low part of the green curve, or is that dwarfed by the uncertainties? And I guess I think that, physically, we know there is a slope, so I'm not too worried about, you know, maybe the whole curve is shifted up or down if we had some errors or poor assumptions or whatever. But I think the fact that there's a reasonable slope there, I think we kind of know from other grounds.

MEMBER BALLINGER: But the slopes are comparable in all of them, actually.

MS. BIER: Right. And that's, more or less, the point that I made a few slides back. Where is this? Maybe it's a few slides forward. There we go. That 800 people is remarkably stable for all plants, all scenarios, and this is, I think, really driven by the nature of the dose response assumption, that, at 2-rem, this is about how many, you know, this is about, if you put 2-rem over 800 people, that gives you approximately one fatality or whatever. So, yes, I would expect those slopes to be --

MEMBER SCHULTZ: Well, that is, in fact, how it is derived. And so one gets back to the discussion about whether linear no-threshold is something that ought to be used. We had the comment this morning with regard to Fukushima, even though we have premises associated with the relationship between dose and fatality, latent fatalities from cancer, we'll never see them. We'll never be able to determine that difference, so one begins to try to put into perspective what this means and whether we shouldn't be determining a way to look at the threshold model.

MS. BIER: So one colleague of mine who's actually a consumer safety attorney educated me on the fact that someday we may know biologically what caused somebody's cancer and that there are markers that can determine whether you got cancer due to radiation or due to smoking or due to what you ate or whatever. So someday we may know the answer to that, but I agree it's not going to be from just counting up cancer fatalities.

MEMBER RAY: Does he think that you can tell the difference between the background radiation and --

MS. BIER: I don't think you would ever know that.

MEMBER RAY: I wouldn't either.

MEMBER CORRADINI: I'm trying to think of the name of the national academy continuing committee that's essentially looking at Hiroshima and Nagasaki and whether it's a neutron dose or it's essentially a dose from an unusual isotope, such as cesium, versus what you'd have in natural background, there is a difference.

MEMBER RAY: Well, all right.

MEMBER CORRADINI: I mean, at least in terms of the incidence because, if I remember correctly from this national academy, what essentially led to the BEIR studies is that neutron dose is actually, instead of linear here, neutron effects are actually super and others are below linear.

MEMBER RAY: But that allows me to have neutron dose.

MEMBER CORRADINI: I'm simply saying, though, that the source of the radiation could be --

MEMBER RAY: Okay. I stand updated on that. But there are also other things that are subject to linear no-threshold, release levels and things like that from normal operations that get affected by what we're talking about because if we begin to project down into that regime, there's more than accident sources for manmade radiation that people are exposed to.

CHAIRMAN STETKAR: Anything else for Vicki? If not, thank you for subjecting yourself to the grilling. We will recess for lunch and reconvene, I'm going to be a hard-assignment on this, if you can use that term, we will reconvene at 12:45.

(Whereupon, the above-referenced matter went off the record at 11:38 a.m. and went back on the record at 12:49 p.m.)

CHAIRMAN STETKAR: We are back in session, and we're going to have a presentation from the Dr. Robert Budnitz. And, Bob, John Lai is running your slides for you, so you have the floor, sir.

MR. BUDNITZ: Okay. I want you to start, keep the cover slide up for a minute before I go to the ones with the content. And if you read the title, I'm going to stick exclusively to try to answer the question that I pose in the title about whether these large external events, you know, large hurricane, tornado, earthquake, might force us to think about societal risk and societal risk goals and the like and the differences. Why might these need to be treated differently in any policy on societal safety goals?

And that's the thing I'm going to address, but I have to preface this by telling you that I'm an employee at the Lawrence Berkeley National Laboratory at the University of

California. It's one of the big DOE laboratories. But I didn't do this for them. I did this at home on the weekend, and this is private, okay, even though my attribution is there and you can see how to reach me. It was important for me to say those many words.

So I'm just going to stick to this narrow subject, and I hope I can get the whole thing in 15 of my 30 minutes. Go to the first slide.

The first slide is more general than external hazards, and I'm just going to explain what I think is, I'm going to talk about what's needed in a formulation of a societal safety goal. My view, no matter what societal safety goal, it requires analysis of the various non-human health impacts. We're talking about non-human health. We're talking about other than fatalities and latent cancers. And so, of course, in order to do that, you have to be able to do analysis. You have to analyze property damage; radiological damage; economic disruption, some of which is radiological and some not. You know perfectly well if you have a reactor accident and you have to evacuate and somebody loses three days of income because they can't work, well, that's economic disruption. It's not radiological. And then, of course, there's the non-economic, like disrupting the household and the community and the social fabric.

So you have to be able to do analysis because you have to be able to say, gee, does a reactor meet it or does the fleet meet it? And, of course, at the bottom I said somebody is going to have to decide whether there's some sort of expected value of the consequences. And, of course, there's the frequency in the consequences together, or perhaps it's a distribution capturing our state of knowledge of the consequences. You know perfectly well that the current safety goals really are a single number which represents the mean of some, you know. But there's a whole lot to think about there.

So I'm going to concentrate on what sort of analysis one might be able to do because it's a large external hazard.

CHAIRMAN STETKAR: Bob, Bob? We hear most of what you're saying, but you occasionally cut out. Are you on a speaker phone or are you on a hand device?

MR. BUDNITZ: No, I am on a speaker

phone, and this phone that I'm on doesn't even have a hand device.

CHAIRMAN STETKAR: Oh, okay.

MR. BUDNITZ: Maybe I'll just stand back. Is the volume too high?

CHAIRMAN STETKAR: Well, the volume is up and you do cut out every now and then.

MR. BUDNITZ: Maybe I'll move back from the phone. Does that help?

CHAIRMAN STETKAR: Try it. Keep going.

MR. BUDNITZ: All right. So I'm now on the slide called distinctions. I'm going to make three distinctions, and I know no one is going to disagree with these, but these distinctions are important. The first distinction is a large external event, an earthquake or a hurricane and so on, can cause important off-site impacts in the absence of a nuclear power plant. We know that. That's the point. And some of these impacts are similar to a nuclear power plant accident, right? They're similar.

And one of the things I'm going to try to address in a few minutes is, because some of those impacts are identical actually or similar, untangling them, there's a question about whether you can untangle them or not. And I'm going to conclude that you can, but we're going to come to that.

The second distinction is that some vital emergency protective measures, both on-site and off-site, may be very different, very different meaning, first, it's very different whether you have to take this protective action because it's a hurricane than it is because it's a reactor. And then the third case is, well, it's a hurricane with a reactor. All three of those cases are different, and we're going to have to think about that as I go along. One example is the difference between evacuation, which is rapid, and relocation, which need not be.

And the third distinction is that some emergency protective measures, both on-site and off-site, may be much more difficult to implement in the presence of a large external hazard. And that's obvious, too. Think of a great big hurricane that's blowing along for 18 hours or an earthquake that knocked out the bridges or you can name it. Of course, some of the protective measures may be much more difficult.

So those distinctions have to be kept

in mind when I move on to the next slide. So go to the next slide. It says questions.

Now, after the event, this is the hurricane and the earthquake, and after the nuclear power plant accident, here I'm postulating they occur together, I'm asking a question: is it easy, difficult, or impossible to distinguish the power plant-caused impacts and the non-power plant-caused impacts? Now, of course, it's easy to say the radiological can be distinguished, but a lot of these aren't radiological. And one of the questions I'm going to ask is, well, for the non-radiological ones, can you distinguish? And I'm going to ask the question in the context of Fukushima because everybody in your room is pretty familiar with what happened at Fukushima and afterwards, too.

So let's look back at Fukushima. Is it feasible, looking back, to distinguish the nuclear power plant-caused impacts from the non-power plant-caused impacts? And I'm not talking about the radiological ones, which, of course, you can distinguish, but the non-radiological ones. Well, you know, there was huge disruption to the social fabric of the community because of the tsunami, and there was another disruption to the social fabric of that same community because of the reactor. Now, some places didn't get affected by the tsunami. They're inland, and, of course, you can distinguish those. That was the reactor. But some of them along the coast, it was the same folks or the same houses and so on.

So looking back, you have to ask the question is it feasible to distinguish the non-radiological side of these impacts, the economic disruption and so on, for the power plant from the one that isn't from the power plant and came because there was this earthquake or hurricane or tsunami or whatever.

Now, notice my point, the third bullet. If it's not feasible to distinguish these, then performing prospective analysis is also not feasible. Prospective analysis is analysis we would now at a plant. You know, I'm looking at a particular plant, like Diablo Canyon or maybe it's Turkey Point, earthquakes and hurricanes. You have to be able to do a prospective analysis whether or not a plant like Diablo with earthquakes or a plant like Turkey point with hurricanes is or is not going to meet the goal that you decided you were going to write down. And I wrote at the bottom, crucially, without a useful analysis, a societal safety goal tied to these impact endpoints couldn't be implemented, right?

So to implement any safety goal of this kind that you come up with or that we come up with or that anybody comes up with, you have to ask and answer the question whether you can do the analysis, and that comes down, in part, to whether you can untangle these impacts. And that's a question I'm going to address next. Simple enough.

Turn to the next one. It says my bottom line.

The first bullet is to tell you that, yes, I believe it is feasible, but I have two other things I want to say first. This is important. I am absolutely convinced that NRC's authority extends to a concern for the impacts other than radiological impacts, the radiological health impacts, that come from the power plant, from the nuclear power plant. I'm sure of that. Although the NRC has in its safety goals concerned itself with the radiological impacts today, you know, the objectives are prompt fatalities and latent cancers, I am absolutely convinced that the NRC's authority extends to a concern for the non-radiological impacts, these things like the disruption of the social fabric and stuff like that.

Why? It's easy to explain. Go to the original legislation itself. The NRC is charged with protecting health and safety and the environment and the common defense and security. You remember those words. And the environment and the common defense and, you know. And, surely, the disruption of society, even if it's not radiological, is within the NRC's authority to regulate a reactor to minimize those things to a certain level they decide to. I'm sure of that. If anybody there doesn't think that, we got to talk about that. But I'm sure that their authority surely extends there. The question is here how to do it and whether they ought to.

Now, second bullet. I am convinced that, in some major hazard events, there are two types of non-radiological health impacts that will occur, those due to the hazard itself and those due to the power plant, the nuclear plant, right? We saw that at Fukushima. By the way, some of it was tsunami, but some if it was actually earthquakes, too, you know? The earthquake knocked out power, and, had there not been a reactor accident at all, that power was going to disrupt businesses, even businesses not harmed by the tsunami. It took a long time to repair that power, so there were business impacts, you know. You understand that.

So I'm convinced that in some of these major events I'm talking about where they occur together, they will both occur, the external hazard itself, the tsunami, the hurricane, the earthquake, and those because it's a reactor.

Now, here's the bottom line that's important for me. I'm convinced that it is feasible to distinguish which is which, even with the uncertainties. That's a very important point. We're going to come to that, and I'm going to explain why. You see, if it wasn't feasible to untangle which is which, then, if they're important, then you couldn't have a safety goal because you couldn't analyze it so you couldn't know what the hell to do, right? Excuse me for the language. Therefore, it's really important that we understand together and we agree together it's feasible to untangle these things because, if we couldn't, my previous slide convinces me to promulgate a safety objective --

MEMBER CORRADINI: Bob?

MR. BUDNITZ: Yes. And I'm almost done, so, yes, stop here. Go ahead.

MEMBER CORRADINI: Bob, this is Corradini. So I am convinced that it is feasible based on what? Based on analysis? Based on your feeling? Based on what?

MR. BUDNITZ: No, based on analysis. No, excuse me. I have looked at the impacts at Fukushima, okay? The impacts that are non-radiological that occurred from the tsunami, that occurred from the earthquake that preceded it, and that occurred due to the fact of the power plant. And although some of them are similar, even the ones that are similar I'm convinced you can do a reasonable job of disassembling which was which and, for most of them, although they're similar, you can really tell which was which, okay?

We have a site, a particular site. It could be any one of our 60 sites in the U.S., and we're running an analysis like this. And we're going to have some of these impacts are going to come from the event itself and some are going to come from the reactor, and I am convinced that you can do a reasonable job, even with uncertainties, of disentangling those and, therefore, attributing which ones come from the power plant.

CHAIRMAN STETKAR: Bob, this is Stetkar. Do you do that -- I was trying to make some notes here. You can't do that in only looking at short-term evacuation, can you? You almost have to look at the effects of long-term relocation and timing for repopulation of the area.

MR. BUDNITZ: Yes, sir. Yes, sir.

CHAIRMAN STETKAR: Restoration of infrastructure, right?

MR. BUDNITZ: That is one of the major things that we need to be concerned with.

CHAIRMAN STETKAR: Okay.

MR. BUDNITZ: Let's pretend it wasn't a tsunami. It was merely the earthquake. Let's pretend at Fukushima it was only the earthquake, there was no tsunami. But the earthquake caused the core damage accident. We're just pretending. And the same core damage accident occurred, it was the earthquake and not the tsunami, and we had those releases, right? Well, I'm convinced we could disentangle which was which. I've looked at it. I've actually studied the various impacts, you know, the different ones. And although there's some, I won't call it confusion, there's some that are entangled enough so that it's hard to tell for sure, I'm convinced they're not the major piece of it and that you can do an attribution and that you can come up with something that, even with uncertainties, is enough to actually use, if you had to use it to figure it out.

Now, if you're not convinced of that, then we can't proceed with a policy because you can't do the analysis. But a lot of these are very long term. You know, if somebody's business is interrupted forever, you know, that person is out of business. You can work out what that impact is. You know, there's a certain amount of money and a certain amount of social fabric. There's a whole bunch of stuff you have to try to figure out what the measures are, whether they're a utility or whether you monetize them. There's a lot of issues, but whatever they are I'm convinced they can be disentangled.

Now, the statement that it's feasible to disentangle them isn't the same as saying that we can do it. So turn to my next slide, okay? I'm convinced that the NRC, and I mean the NRC Office of Nuclear Regulatory Research, I'm convinced that the NRC needs to undertake research to study the issues for doing this type of analysis because, absent that research -- first, you need the research to confirm what I said. But more to the point, you need the research to work out a methodology for doing this that addresses the issues that have come up, some of which we talked about this morning and some of which I'm touching on here and some of which we can talk about later.

Now, let me go on. I'm convinced that the analysis methodology, once developed and exercised, will be able to distinguish, okay? Until the research is undertaken, my being convinced isn't sufficient. That research is going to be necessary, in my view, to support any societal safety goal formulation you come up with. That also covers accidents like this because, remember, if it's a pipe break or a LOCA, then there's no other stuff to disentangle. But if it's a hurricane or the earthquake that caused it, there is stuff to disentangle, so you have to be able to do that or else you can't implement the safety goal because you can't do analysis, so the whole thing is hopeless.

We really need to convince ourselves not only that it's feasible but how to go about it and what the uncertainties are and how to capture it and you have to guidance document and people have to be able to do the analysis for every site. There's a bunch of stuff, all right?

And to me, that is an appropriate role for the Nuclear Regulatory Commission Office of Nuclear Regulatory Research. And how would I know? I was once its director. Probably most of you in the room know that, but maybe some of you didn't. I was once its director. I know perfectly well what the mission of the Office of Research is. Go read the legislation and, furthermore, go read the Commission's policies.

Now, whether the current Office of Research or the one we've had would have ever undertaken something like that, that's somebody else's problem, although it's my problem, too. I'm firmly convinced it's very unlikely that the Office of Research in the last five or ten years would have undertaken research like that. Part of the problem is somebody is going to have to convince somebody that it's money well spent, right? And we have the cockeyed user-needs business, which is crazy.

I'll give you a little extra about that. It will only take 30 seconds. I am convinced that if it was 1999 or 2000 and Norm and Saul -- if you don't know who Norm and Saul are, it's Rasmussen and Levine -- came and said we want to develop a new methodology called TRA and we want the Office of Research's support, because that's who did support it, it was the predecessor of the Office of Research and afterwards it was the NRC's office, right? They would go over to NRR. NRR would deny them a user need, and it would have never got off the ground. I'm convinced of that, and if you're not go back and look at the history when it was being developed, but they didn't use it after it was developed. And it's in the record.

So we have a problem there, but I am convinced -- look at my first bullet -- that the NRC Office of Research needs to undertake research to study these issues so that we will have the methodology in hand to support the policy development we've been talking about today. And absent that, I don't think, you can talk about it all you want, you can't write something down until you can do the analysis.

One last slide and I'm done. This is my very last slide, my bottom line continued. Crucially, and this is the same thing I said before, I'm convinced that the NRC needs to regulate so as to assure that entire spectrum of impacts from an MPP would be acceptable, and that includes these non-radiological. That's what I think. And that requires being able to identify them and to analyze them quantitatively. Now, it's easier analyze them quantitatively if the accident emerged from a pipe break or a LOCA. It's harder if it emerged because there was a concurrent tsunami that caused it. But I'm convinced that NRC needs to regulate these things; and, therefore, they need to have some policy that tells everybody what's acceptable, like we have with the safety goals now, and that that requires being able to analyze them and --

CHAIRMAN STETKAR: Bob, you're breaking up again. In fact, you just went away.

MR. BUDNITZ: I'm done anyway. That's my last slide.

CHAIRMAN STETKAR: If you had a real punch item to get in in your last two sentences, could you repeat it? Because we lost most of the last two sentences.

MR. BUDNITZ: Yes, it's easy. Because I'm convinced the NRC needs to regulate the entire spectrum of impacts, I'm convinced we need an analysis methodology that can do that; and, therefore, I'm convinced that, since we don't have it, the NRC needs to undertake research to develop that methodology and demonstrate it's efficacy. That's my bottom line.

CHAIRMAN STETKAR: Thank you.

MR. BUDNITZ: Which goes in this external business to distinguishing which is which. You know what I mean by which is which.

CHAIRMAN STETKAR: Yes, yes.

MR. BUDNITZ: And that's the end. I did it all in about 17 minutes.

CHAIRMAN STETKAR: You're amazing. That was Stetkar. You don't get many compliments. It's a backhanded one anyway.

MR. BUDNITZ: I love you.

CHAIRMAN STETKAR: Yes. Anything else for Bob? Any members have any questions for him? If not, what we're going to do, Bob, is we're going to mute your line because, even if you don't say anything, we get pops and crackles in here.

MR. BUDNITZ: So, listen, I can mute mine or else I can go off and come back in on the other number like everybody else.

CHAIRMAN STETKAR: Whatever you want to do. I just want to alert you to the fact that if you --

MR. BUDNITZ: No, no, no, no issue. I'm done.

CHAIRMAN STETKAR: We won't hear you if you're going to scream at your phone, whichever one you're on. And with that --

MR. BUDNITZ: Oh, with that, do I get to have an intervention on something that happened this morning?

CHAIRMAN STETKAR: No. Actually, no, we're not, I don't like the different presenters having, you know, question and answer periods among themselves. You're presenting to the Subcommittee, and we're digesting your input.

MR. BUDNITZ: I'm done.

CHAIRMAN STETKAR: Thank you. The next item on our agenda then is -- John will get that muted up there. Rich is back up with another part of his continuing presentation.

MR. DENNING: This is the workshop,

yes. And so I'm going to discuss --

CHAIRMAN STETKAR: Is your mike on? It is? Okay.

MR. DENNING: Yes, it is. Okay. This will be short. I'm going to describe a workshop that we had in 2012. First of all, INEST is a program that Idaho National Laboratory put together to try to extend or improve their relationships with universities. That is, get more interaction between universities and INL staff, and they implemented it through the five universities that are part of the consortium that runs INL. And the program was called INEST. It actually no longer exists, but in that program when it did exist I was in charge of representing Ohio State University a reactor safety group under INEST and, originally, Nam Dinh was my INL contact. And then when Nam went to NC State, then Bob Youngblood. See, so there's all this incest that we have here.

And one of the programs that we supported was, indeed, Vicki's program. We pushed that and used INEST designated internal research and development funds at INL to do that.

But in addition, we undertook a workshop on safety goals. We had it at University of Maryland. We recognized that if anything were going to be done about safety goals that it probably would have to work up from an ACRS, as it did originally with the original safety goals. But before we would come to the ACRS and the NRC, we wanted to have some discussion of just the various issues associated with formulating a safety goal and identify some next steps.

So we held a meeting at the University of Maryland, a large number of participants, some that are here today. And that's not totally everybody because there were some gate crashers that came in that also participated, but those are the participants. We had some breakout sessions, one on safety and performance goals and measurers, candidate measures of societal impact. We had a breakout on site risk issues, multi-unit considerations. Karl Fleming was there, as you might have guessed, multi-unit considerations, level 3 analysis needs, and then a breakout on regulatory implementation issues, quantification on societal impact, and potential regulatory impacts, just the type of things that maybe we'll discuss a little bit here after my next presentation.

The workshop, in my opinion the

workshop wasn't quite as successful as I had hoped. It was too little time to really develop these issues. George was there and said, well, you've got to wait for NUREG-2150 and then that's going to solve all of these problems anyway. And then there was a lot of concern expressed that, if we were going to do things, we needed a smooth transition, and I completely agree with that and I'll talk about that in a second. And the concern that establishing a new safety goal might be too radical a change for a fragile industry.

And that's the workshop. And there's a report on the workshop, but, in all honesty, there's not a lot of real meat that came out of the workshop. Interesting discussions but very few conclusions.

Okay. Now, we need to switch over to my other -- I don't think you need, unless anybody has any questions about the workshop, I think that we can go on.

Okay. So now I want to talk about alternative safety goals and risk measures and a little bit about, if you were going to implement this, how would you do it, and also the key question: would it make any difference to the way we regulate or the safety of plants?

I think there are some things that are fundamentally wrong with the QHOs, as we have them. We've talked about the latent cancer fatality QHO. When I say fundamentally wrong, I don't really want to really dismiss them. I think that they do provide an important goals for us. Obviously, we don't really regulate according to those, but if you look at risk-informed regulation, then the surrogate measures, CDF and LERF, that's really how we implement risk-informed regulation, which I think is important.

We've talked already about how the latent cancer fatality QHO is really an individual risk. It does not really address the true nature of societal risk. And as I implied before, I think that we really have distorted the view of human health risks. Now, maybe it was unavoidable. Maybe the public was always going to be concerned about nuclear and not be able to think rationally and make rational decisions based upon their own individual health risks because it is complex. But there's no question that we've kind of shot ourselves in the foot often, and I think it's very clear that, as far as the health risk of the people in the United States from nuclear power plants, it is just extremely small. It's not something that anybody should worry about any time in their life. I mean, that's kind of what it means to be not significant, but I think it's even well below the not significant. And the fact that we are now moving away from nuclear power in a time when it's going to be so vitally critical to us is a great concern to me, and I'll talk about that in a little bit.

And SOARCA has been part of the understanding that even NUREG-1150 provides kind of a mischaracterization of risk. I mean, it puts it into an important perspective, but it's a perspective that's very difficult for the public to understand.

I think that if we look at the individual things, if we look at early fatalities, I think that the potential for early fatalities is just extraordinarily small. Even at Chernobyl where we saw first responders that had early fatalities, they were really first responders, there were firemen on the roof. It wasn't members of the public that really, despite a colossal release of radioactive material even exceeding the things we estimated in 1400 and for reasons that are not applicable to light water reactors.

So I think LERF in particular is an issue for a couple of reasons. First of all, if you look to see the way LERF is calculated today, it's done in a very formalized way, going back to NUREG-1150. People don't do really Level 2 or Level 3 analyses for their plants and come up with LERFs. They use prescriptive things that go back to NUREG-1150. And associating that with early fatalities that are more fictional than real I think is an issue for me.

So I think that there's an element of early fatalities that just isn't real, and it's a specter out there for the public and how we change that specter is hard for me to understand. But if we didn't give it so much emphasis here, then maybe people would start to understand or maybe we could make the story better.

Now, even latent cancer fatalities, there's a lack of reality to those because of the LNT, which I think we certainly know that it's not linear and the societies, like the American Health Physics Society, says shouldn't apply it below 10 rem. But even when we look at those latent cancer fatalities, they really represent a very small risk to the public, even though there may be a fictional aspect to those, as well, using LNT to do that kind of calculation.

So I think that we have overestimated what the human health risks, radiological risks are and we have definitely underestimated this societal risk, land contamination that we're talking about here. And I do think that, I think that that really is the dominant risk, and, if people thought rationally, I think they would say don't talk to me about human health risks from radiology, that is so trivially small. But when you talk about land contamination and potential for large areas of land contamination, at least for some countries, that certainly becomes a major consideration.

Now, the studies that I did say this is not a dominant risk relative to other things, the background societal risks with which we live and which we have some impact. Even though we may not think we have much impact on some of them, on almost all of them I think we do have some impact.

There's also an issue that's out there, and I'm sure Ed is going to be talking about it when he talks, and that is that we're going a different direction from the Europeans. Europeans are adopting requirements for the mitigation of severe accidents in all their plants. They're going to what they call no release. And we realize, particularly risk analysts realize, you really can't do that. I heard statements by people like Raj Sehgal, who I think all of us know and appreciate, that said if you identify a vulnerability that could potentially lead to a release, you've got to address it. Now, we can't go that far. I think that we have to take this in a risk perspective, but I think we also have to recognize that, at one point, we were thinking we're going to rationalize our requirements with the European requirements, the world's requirements, and I think it's important to recognize we are going in a different direction from most of the rest of the world in this regard.

CHAIRMAN STETKAR: Rich, may I interrupt you there for a second? Because I've been reading some of the stuff coming out of Canada that seems to have a little bit of traction, at the IAEA anyway, and they seem to take some sort of middle ground, if I can characterize it that way, because they don't say no releases. They, indeed, have a frequency based on, you know, certain inventory of terabecquerels of cesium. Would that work?

MR. DENNING: Absolutely.

CHAIRMAN STETKAR: Okay, thank you. I wanted you to say that.

MR. DENNING: And, in fact, I'll talk about that a little bit. Okay. So if we're going to have the societal goal, you know, I proposed a societal goal that had CCDF and the comparison to CCDF with a 0.1 percent, the 0.1 percent, of course, with the history of the way the other QHOs are. But if we tried to develop this societal risk, as I have done, it's not an easy task.

So, basically, then there's a question of how complex should this -- if we're going to compare it with something and you saw the way I developed a comparison and people had some criticism of some of the things that were in there and the way it's done, and I agree it's not easy and there's no correct way. But I do think that if you have the stakeholders involved, you could come up with something that rationally, I think, was a background of societal risks. And although there's some feeling, I think Joy has some feeling that there's a difference in the character of a nuclear power plant accident. I think there are more commonalities than there are differences, as far as societal impact and things that can really disrupt our society.

So the question of how complex should that economic analysis be, what should we include in that? Is cost of power replacement, is that a legitimate concern for the NRC? I think there's even a legitimate concern, although Bob was kind of saying he's absolutely convinced that this is the NRC's business, but I could hear arguments to that. But I do think it's the NRC's business.

So as far as the safety goals themselves are concerned, I think they're fine. I think the health safety goal, the two societal safety goals, as I interpret them, I think they're fine. What we really need a QSO. It's a good one to the quantitative health objectives.

And so you've heard the suggestion or you've seen the one that I've kind of posed, which is the 0.1 percent on the CCDF. You could also do that on the prime average risk, as I've said before, and that's actually less constraining because the CCDFs for the nuclear falloff have their knee quite a bit earlier than the knee, assuming there is a knee someplace out there on a background societal risk on that, it's really a lot easier for a plant to satisfy or for all the plants to satisfy a QSO on that time average.

But I think an appropriate surrogate could be large-release frequency. Again, I've talked about why I dislike LERF and why I think it's inappropriate. I think that one thing you could do is have a fraction of core inventory, and I've looked to see, well, at what fraction of core inventory would you not have to have any off-site decontamination? That's a pretty small level. It's smaller than this 0.1 percent that I suggest there. But 0.1 percent I think is a pretty reasonable goal for a large-release frequency, and that corresponds to about 10^4 curies of cesium, which sounds like a lot but it's obviously not small.

Okay. Now, another question, is it necessary to perform site-specific Level 3 PRAs for every site? I would hope not. If site-specific results aren't required, is it necessary to re-do existing Level 3 PRAs for a variety of sites, and I absolutely think that that ought to be done and I also think that, and I don't know if I mentioned it just yet. So the NRC is doing a Level 3 PRA, and it kind of got stalled a little bit, I think, by Fukushima. But I certainly think that one of the objectives of that should be to try to say what are the alternative measures that we might consider for a QSO? Even though I know the NRC is not ready to step forward along the lines of that, I think we should be doing the research.

Beyond measuring land contamination and -- so I might not have made it clear, but I didn't really look at latent cancer fatalities within the societal risk as I formulated it. But I do think that's appropriate. In the paper, there's some comments that some work that Vinod had done that indicated that that contribution is really pretty small, that is the latent cancer fatality risk, the reality is you monetize it and it really is a pretty small risk. But I do think it actually belongs in there, among other things.

So any major new implementation for the existing nuclear power plants could have negative societal implications that I think are substantially worse than the societal impact of an accident. I think that I would be very reluctant at this point to introduce a concept, a new concept to societal risk that would get backfit to new nuclear power plants if our objective is to minimize societal risk because I think, and I kind of say it down there at the bottom and it's a major concern for me, I think we need a rational energy policy that looks at least 50 to 100 years in the future because I think that we're doing things today that are going to, that our grandchildren are going to live or die to regret. And in particular, one thing is I don't think we're ever going to really address global warming, not the way I see what's happening among different countries. But even beyond that, I think the greater risk is what happens when fossil fuels come to an end? And they will come to an end, it's just it's a matter of when. And maybe it's 100 years, maybe it's 50 years. If you look at proven reserves, it's under 50 years. And we ought to have a risk-informed approach towards that, and we ought to be doing things today to really replace fossil fuels. And what the President has proposed has such limited likelihood of success, but also it just doesn't recognize the scope.

And because it's politically

unsuccessful today to say it's going to cost a lot of money to do it, the reality is it's going to cost a lot of money to do it, and we're not going to be able to do it unless we do. And I think that people haven't done the simple engineering analyses that indicate that we can't get there on renewables. It's got to be part of the mix, but we can't get there. We need nuclear energy, and the thing that's going to blow all of this out of the water is we're going to shut down a hundred nuclear power plants.

So my suggestion is that we do the research on this and we establish a QSO for future plants because I see a world in which there's at least four or five times as much nuclear energy as there is today, and a lot of it isn't just electricity energy. Only 40 percent of that energy that goes to things is electricity. We focus on electricity. That's only 40 percent of our future problem.

So, anyway, I say future goal because we're going to site reactors in areas that we today don't find acceptable. And if we're going to solve this problem, we're going to have to have nuclear power. Not for this set of reactors because that risk is small, it's manageable, we live with it, but we prepare for the future that I think is essential.

So that's the end of my pitch. And you see it's a little bit broader in pitch than just the QSO. I'm done.

MEMBER SCHULTZ: Rich, I appreciate your presentation and especially the thought process that you've gone through in the last couple of slides, but could you go back to your slide seven where you talk about the societal objective that might be proposed? And the last bullet for the surrogate, I'm not sure I'm getting the connection with the large release frequency and then you come down to a representation of that as a fraction of core inventory. Could you delve into that a bit more?

MR. DENNING: Okay. So people have suggested LRF in the past. DOE has talked about LRF as an appropriate thing, rather than large early-release frequency. So then the question -- because, again, I think it also addresses a problem that's not a real problem. I think of early fatalities, which I don't think is a real problem.

A large release frequency would say,

yes, we recognize that -- I mean, you can't have no release, right? And you can't assure that you're not going to have release larger than whatever your goal is. And so my propose for a large release frequency that's quantified at about the 0.1 percent is that that's a very limited off-site land area for decontamination. There would be some, but it's not anything like the Fukushima. It's much more localized. It's not just the plant site.

MEMBER REMPE: Does that have an adverse effect on the small modular reactor versus a large power reactor? I mean, wouldn't an absolute number of curies that are allowed be more --

MR. DENNING: Yes, and that is a possibility. So I was basing this on a large, say 0.1 percent. And then I said 10^4 curies of cesium, then that brings it back towards the small modular. And I do think that whether there's small modular for electricity production, I think there would definitely be small modular for processed heat applications in this world that I see where my kids aren't going to freeze in the cold.

CHAIRMAN STETKAR: I mean, the Canadians have sort of addressed that because they have a frequency of a particular quantity, terabecquerels or curies or whatever, of iodine to trigger an evacuation at a frequency level and at a frequency of quantity of cesium for long-term relocation. Both of those are associated with -- and it's an absolute magnitude triggered to evacuation and interdiction and relocation, which, again, would favor smaller reactors because it's an absolute value and not a fraction. And it does address early, it does kind of address this early versus late defects.

MR. DENNING: And that's kind of my thoughts, too, about iodine and what it potentially affects shorter term. But, again, I also think that part of this perspective relates to we need a really rationale approach towards evacuation versus relocation.

MEMBER CORRADINI: So can I ask a question? So I guess I'm still curious about the -- Steve went back to the slide that I was going to ask about. So you got to the 0.1 how?

MR. DENNING: 0.1 percent?

MEMBER CORRADINI: Yes.

MR. DENNING: Well, I was looking at what the amount of land contamination is that one could potentially get, and one of the things I wanted to look and see is, well, recognizing a site boundary of maybe a quarter a mile or something like that, what kind of release would there be where you would be pretty comfortable that you would never have to decontaminate? And that's a very small release of cesium, and I don't see any reason to really say you would have to be that low.

MEMBER CORRADINI: I'm translating that, well, I guess I'm asking --

MR. DENNING: I'm translating it to say that is a level that is greater than just the site boundary, but it's definitely a neighborhood, a near neighborhood.

MEMBER CORRADINI: So if I had nine reactors, would I have it for the site or would I have it for just the each reactors?

MR. DENNING: Oh, now there's another question. One of the things we haven't really addressed in all of it, I mean, as part of the dilemma of safety goals is we haven't really addressed the multiple reactors on a site and how do you really treat that. We don't have a real approach.

MEMBER CORRADINI: So you would have

that -- I'm just trying to understand your suggestion. So just to kind of summarize, you wouldn't impose this on current reactors, you would impose this on something in the future?

MR. DENNING: All future designs. All future power plants.

MEMBER CORRADINI: So even -- no, go ahead.

MR. DENNING: So there's a risk logic to that, too, limit to lifetime, right? That limits their potential to impact us. And even at that, you know, to me, as I look at the societal impacts as I've characterized them from the nuclear power plants, those are acceptable risks, as I see them. Maybe it's not less than 0.1 percent, but, to me, that's an acceptable risk and also recognizing that that part of the risk is going to fade out and the future reactors are much lower. I mean, I look at the gen-3 plus designs and stuff like that, and they're going to be safer reactors. Current reactors are safe enough in my mind without any changes of that nature, but there's no reason why we shouldn't establish stricter criteria on them.

MEMBER CORRADINI: So one last thing,

because there will be other questions, so the 0.1 percent is at some probability level? I mean, to get back to John talking to a previous speaker, you can't just put a consequence, so you have a probability with that consequence, so it would be like LERF that I'd have some sort of CDF and then I'd look for an order of magnitude improvement on the CDF not to exceed 0.1 percent of the release? Is that how I understand your thinking is?

MR. DENNING: Yes. So instead of, if you think about Reg Guide 1174, you would have comparable things in there that, instead of being CCDF and LERF or CDF and LRF.

MEMBER CORRADINI: Okay, all right. Thank you.

MR. FULLER: Excuse me. This is Ed Fuller, Senior Technical Advisor on Severe Accidents in the Office of Research. And I wasn't always in the Office of Research. My first five and a half years here was in the Office of New Reactors. And given how we were regulating or reviewing the design certification applications, one needs to know that the concept of large release frequency is used and it does not have a singular definition. We left it up to the applicants to provide their own definitions, and one of them, namely Areva, had something very close to what Rich has put up here.

So, in fact, if you look into the standard review plan for reviewing, you will see guidelines for regulating against large release frequencies. So we have already got it in our regulatory basis for the new reactors.

MR. DENNING: So that gets, again, to that question of, if we had a QSO, would we do anything actually significantly different? And I'm not absolutely sure that we would, but, conversely, it seems to me that we have what I think is the dominant risk of a nuclear power plant accident, and we're not addressing it directly.

MEMBER SCHULTZ: Well, in that regard, Rich, it comes back to the final statement you made is that it would seem appropriate for us if there was an energy policy or there was a statement or objective, put it just to that that we should have 500 gigawatts of nuclear power in 50 or 100 years, whatever the case may be, that, therefore, as the society moved toward that goal, we would have this kind of thinking in place.

MR. DENNING: Yes.

MEMBER SCHULTZ: And the sooner the better, if you will, to get an acceptance that this particular criteria is appropriate and would guide or allow that development to, in fact, take place and put into perspective the current safety goals and the current success in meeting those safety goals, and the importance of having this kind of safety goal is to be able to move forward to that population or that production of electricity, whatever the population of plants would be with large and small reactors.

MR. DENNING: You said it actually better than I did.

MEMBER SCHULTZ: And I said it because I think what we've heard today is that there are a number of key points associated with moving forward in this way, and there's four or five really good ones that, if combined, would be very important to structure such an approach. But that final conclusion as to why one would go forward like this and why it should apply to the current next generation of plants -- I would include, of course, Areva, Westinghouse, and so forth to be included in that -- but to enable the discussion and the technology to move forward.

MEMBER CORRADINI: So since nobody is asking a question, I'll ask anyways. I was just asking John privately I seem to remember some commission years ago, I can't remember if it was 2007 or 2008, ruled on whether gen-3 plus plants, which were imminent to be going into construction, certified and going into construction, should have a CDF and a LERF better than current plants, and it was a pass. What's the chance of sub-bullet two of major bullet three happening if even that -- because I know what you're saying and I do agree that if I increase the population of some sort of technology, you should strive for a safer design, and that's kind of what you're saying here. Although you're measuring it differently, that's really what you're advocating. So I don't disagree with that.

On the other hand, though, I don't see even with this a way around --

MR. DENNING: Well, when you say that and if you look at an argument that says we have to have a population of reactors that's significantly larger than the population that we have today --

MEMBER CORRADINI: No, that isn't what I was saying. I'm just saying --

MR. DENNING: I was saying that. That say you've got to make them individually. It doesn't solely mean that but, to have the same level of societal risk, you would have to make them --

MEMBER SCHULTZ: That's what I took from that last part of the discussion is that do the thought experiment where you've got 500 gigawatts of nuclear power, what would you want to have that to be in terms of societal risk? And in order to get there from here, you have to set something in this regard now so that by the time you get to that magnitude of nuclear you've got something that society would be able to say, and in between society would be able to say, hey, we're doing the right thing, we're going in the right direction.

MR. DENNING: Even if you have to convince an audience out there, a population out there that the reactors -- I mean, it's hard enough for us to convince them they're safe enough now, but you have to make a convincing argument that these are safer reactors than the ones we have today without saying that today's reactors are unsafe.

MEMBER SCHULTZ: Right. And my take on a decision that says, oh, everything is fine with the current safety goals, we don't have to move forward, I think that thinking is associated with where we're going to build ten new plants this year, maybe in the next ten years we'll build 40 or 50, but this thinking is different. This is to say that that's not where we can go as a society and address things like global warming and fossil fuel depletion.

CHAIRMAN STETKAR: Anything else for Rich? Rich, thank you very much. It's really interesting. We're way ahead of schedule, and I'm going to take the opportunity to keep us ahead of schedule. And if Ed Lyman is ready, we'll ask him to come up and give us hi presentation. Ed, you ready?

MR. LYMAN: Yes. Okay. So thank you very much for inviting UCS to present. I'd like to thank the Subcommittee for taking up this issue because I think it's an area where the Commission itself has dropped the ball, and so I think it's important that the ACRS use the flexibility to look at issues that may be not just things that the Commission is chewing over but to try to fill in these gaps.

I wanted to expand the context a little bit and explain why we do think societal safety goals are important in the context of the current regulatory framework, so I would differ from the previous speaker in that I do think we need to address gaps in the regulation in the operating existing plants, as well as future plants, and one of them has to do with the longstanding gap in the safety framework.

Just to recap, and I think I've shown this slide to some of these Committee members before, but UCS strongly supported the Fukushima Near-Term Task Force Recommendation 1. We believe that the regulatory patchwork was and continues to be flawed, as highlighted by the Near-Term Task Force, and that their recommendation of a logical, systematic, and coherent regulatory framework that appropriately balances defense in depth and risk considerations, that proposal has largely been watered down, chopped up, and shelved by the Commission, and we think that was a mistake.

I'm not going to go through the list of issues we think are necessary to fix, but part of them do relate to the implementation of the Backfit

Rule, and that's in two parts. One is the cost benefit analysis and a number of these elements refer to that aspect, but the other refers to the issue of what's a substantial safety enhancement? And that goes directly to the safety goals.

So we believe that the failure to fix the framework and address this loophole that the safety goals were never fully implemented, as they were originally conceived in my reading. We've seen results of this flawed framework, and there were a number of recent either Commission decisions or staff positions that will probably be turned into Commission decisions soon that all have something in common. They were measures that would largely address mitigation of risk, either severe accident or sabotage, by reducing the consequence or the magnitude of large radiological releases, and here this relates to the discussion of the LRF that we just heard because if your safety goal involves LERF, which, depending on how you define it, is either release before consequent with vessel breach or before there's an effective evacuation of the close in population, in any event, just looking at the early releases, you are not controlling for late large radiological releases, in other words after there's been substantial evacuation of the EPZ.

So the expedited transfer of spent fuel proposal and the filtered vent/CPRR rulemaking and the variant of that for non-BWRs, containment protection for PWRs, and Mark III BWRs and regulatory treatment of SAMGs, which overlaps with at least two of those., the decision not to go forward hinged on the application of safety goals to show that you would not have a substantial safety enhancement. And that is directly a result of not considering the consequences of a late release that does not affect LERF but does affect the societal issues of extensive land contamination, etcetera. So that's the gap that still hasn't been filled. And, actually, I went and got ahead of myself, so that was the slide here.

So there were three reasons at least why this wasn't a proper approach. The first was the safety goals were never meant as a litmus test for a substantial safety enhancement, and so the kind of regulatory creep of now applying them essentially as a litmus test I think is improper. And if they are going to be a litmus test, then if they were meant to be the set of safety goals that you want as a litmus test the right set, either are the existing safety goals appropriate and do we need more?

Then there's the issue of a substantial increase. Now, the Backfit Rule refers to an increase. Increase means change. It doesn't mean measuring something against the absolute magnitude of something. So I think that that approach, throwing things out based on the absolute value of the calculated risk below the safety goals is not fulfilling the language of the Backfit Rule.

And, finally, as we heard before, the safety goals, when they're expressed in terms of individual risks, are relatively insensitive to safety enhancements that might address the collective measures of harm. And so they're not useful surrogates for societal risk goals, but, as we heard earlier, that's the way they're being applied.

So first we go to NUREG/BR-0058. That's the regulatory analysis guidelines, the latest version, 2004. It says clearly the safety goals are not requirements and, with the Commission's approval, safety enhancements may be implemented without strict adherence to the safety goal policy statement. So the Commission does have the discretion not to use that approach.

But what about the issue of change in risk? So if you just look at NUREG/BR-0058, the quantitative health objectives do not even appear in that document. That document regulates increase, a substantial safety increase based on a change in CDF as a surrogate. And so the guidance for doing that is spelled out there based on a subsidiary safety goal of 10 to the minus 4 per reactor year. You want a change which is significant relative to that value.

But let's say the draft CPR regulatory analysis, the staff, again, just compared an absolute value of the individual latent cancer fatality risk and said, because the status quo was already well below the quantitative health objective, then anything you do essentially won't meet this threshold for substantial safety enhancement, and I would submit that that is incorrect application.

Now, we get to the direct connection of this meeting, and that's do the safety goals, do they screen events like I described, which affect a late large radiological release that could cause extensive land contamination but not have much impact on LERF or any impact on LERF? And I would call the fact that the current regulatory analysis guidelines don't even allow you, don't have a provision for evaluating a change in the regulations. It would only affect mitigation or consequences, and it says clearly that if delta CDF0, the safety goal screening criteria do not address issues dealing with containment performance, so they be addressed with the safety goal screening criteria.

Now, I ran into that problem before, and it's also similar in RG-1.174, if you want to try to apply that to a regulatory change that doesn't impact CDF, and about 15 years ago I wrote a paper where I came up with this equation which may be the only thing I've ever invented. And that comes up with an effective change in CDF. So if you have a situation where only the consequences change, but you look for the effective change in CDF that would lead to a corresponding change in risk, and that's the equation reviews, where R is, for example, the individual latent fatality risk within ten miles.

So now applying this to CPRR using this formula, and I drew the numbers here from the draft CPR regulatory analysis, if you use this formula, then you find out that the effective change in CDF would be greater than one times ten to the minus fifth. And according to the regulatory analysis guidelines, that's something that might be considered for further regulatory consideration. And that comes to a different conclusion than the staff's approach.

So I would say you need, if you're going to be evaluating changes or some safety goal that impacts essentially mitigation or large late release, then you're going to need an approach where you can actually use that to determine what's a safety significant or substantial safety enhancement.

Now, the last part, we heard a lot about this already, and you can see that I do agree with previous speakers that, even on the safety goal policy statement the language shows that they implied that the individual safety goals were meant to bound societal risks, were meant to be controlling, but they don't actually do that. And so that original logic doesn't apply. And, you know, the original safety goal was specified for 50-mile areas, and we heard this morning that it was judged that the individual risk within 10 miles would be conservative because of the higher average exposure to those individuals. It turns out that is true. That's even true if you evacuate rapidly, looking at the numbers, for instance, from the, again, CPR regulatory analysis.

The resettlement of evacuated zones does lead to long-term cancer risks, but those individual risks are still smaller from the over 50-mile area than the 10-mile area. So it is controlling, but it doesn't appropriately limit societal risk where there are considerations of the aggregate harm. And if you go back to the safety goal policy statement Federal Register notice, Commissioner Bernthal and his comments pointed out that the current safety goals would allow you to site the reactor in Central Park and meet the safety goals, just like they would anywhere else, and that, obviously, something is missing if the answer is there's no difference in, there's no difference in siting a reactor in the middle of Central Park as in a rural area. So it's giving you the wrong answer if you don't have a safety goal that is sensitive to that.

And, again, current analysis verifies that. So, again, going back to the CPRR analysis that looked at both Peach Bottom and Limerick, Limerick has a much higher population density within a ten-mile area, but the individual latent cancer risks are, roughly, similar between the two because, as the document says, a population-weighted consequence metric leads to generally similar results.

Now let's take one societal safety goal that we've heard about already, the risk of long-term displacement. So I want to use this as an example to see where the current population of plants are. And you can just pull off the number that, worldwide, 27 million annually are displaced by natural disasters. I don't know what the comparable number is for manmade disasters, but it's, most likely, far smaller. And it doesn't also specify how long those people are displaced, so that's really an up or down for the current long-term displacement that the NRC considers in some of the recent regulatory evaluations.

So based on that number, the average risk per person is about four times ten to the minus third per year risk that you'll be displaced as a result of a natural disaster. If you look just at the U.S., this is averaged over the last eight or ten years or so, the comparable number is about 1.5 times ten to the minus third per year. So if you were to derive a safety goal from that, again, let's say 0.1 percent of the background risk of displacement, that would be 1.5 times ten to the minus six per year. And if you compare that to the average annual risk of long-term displacement, that's one year greater within 50 miles of Limerick. From the CPR regulatory analysis again, you find out you're comparable or you're above the safety goal. That's about two-tenths times ten to the minus six per year. So the way I look at it or this metric would actually show that there is a reason to take regulatory action if you adopted this metric.

Now, that calculation used what was characterized in the document as a conservative upper bound for the core damage frequency associated with an ELAP, and if you used a lower value, not the most conservative, that might be an order of magnitude lower for the 95th percentile, and so would that conclusion also hold? And then you'd have to get into how would you calculate or define a substantial increase in this case? And the NRC has never answered that question clearly.

If you look at the guidelines from NUREG/BR-0058, again, they don't address something that would largely affect mitigation, as opposed to CDF, but is there a way to try to piggyback on that, essentially, matrix for decision-making to adapt to a situation where you're imposing regulations that will change, essentially, increase mitigation as opposed to increased prevention. And I actually was trying to do that up until last night, but I couldn't come up with an approach that worked. And maybe I'll just describe it.

So what if you wanted to give separate credit to changes that will increase mitigation? So let's say you had, if you look at CPRR, you know that the status quo, let's say there's a certain number of people that would be permanently or long-term displaced, if you applied the water management measures, that would be increased or that would be decreased by a certain factor and if you had filters it would be decreased by another factor, so you can think of those as decontamination factors. So maybe, as your core damage frequency decreases, you might want to give separate credit to increased decontamination factor. So I had a matrix where you had decrease in core damage frequency against increase in decontamination factor. But if you think about that, that didn't actually make sense because it would sort of say that the smaller your risk is the more you get credit for reducing it more. So if your original risk was ten to the minus seven and your decontamination factor was a thousand, it would push you toward crediting, making small risks even smaller.

But something that's worth thinking about is how to come up with a scheme where you could assign or develop a substantial increased threshold for increased mitigation. So that's one challenge I think maybe the Office of Research could take on.

So to conclude, we think the regulatory framework needs to be revised, that you need a wider range of severe accident consequence metrics, including one or more of the collective ones we've heard about today, and that that process has to be able to acknowledge and give proper weight to safety enhancements that affect mitigation and not necessarily on prevention.

And so I will stop there and entertain your questions. Thank you.

CHAIRMAN STETKAR: Thank you, Ed. Any questions for Ed? Members, anybody?

MEMBER CORRADINI: So let me make sure. I think I know the answer, but I want to make sure. You would not distinguish between future plants and current plants in terms of adopting some sort of long-term or societal risk goal?

MR. LYMAN: Well, let's put it this way: we would adopt a new requirement for existing plants because we do think there's a loophole in that, in a Fukushima-like event, needs to be somehow given weight in making regulatory decisions more than it has. But we do believe that new plants should meet more stringent safety requirements than the current generation, so the advanced reactor policy statement which has been, you know, reiterated, it is misguided, in our view. We think if you have the opportunity to achieve substantial increases in safety for the next generation of plants, that should be a requirement and not just a suggestion, and that if any other industry, if you say you'd never use the excuse that we're afraid to require new plants to be safer because then people would start questioning current plants, but that's the mind set that the NRC has gotten itself into.

We think an opportunity has been squandered to impose more stringent safety requirements for the future generation of plants and that's led to some of the issues with the passive systems, robbing Peter to pay Paul. You know, so if they get the same safety margin from a passive system through treatment of non-safety systems or containment performance or elsewhere, so you may end up with something that's not substantially safer in the current generation, and that's the result of the NRC not saying you want to build a new plant then we can ratchet up safety because that's what the public deserves and also the agency.

Collateral outcome would be that you can expand nuclear power without significantly increasing risk to the public, although that isn't a consideration, I think we all understand, the NRC is glad to take. So the short answer is we think you need more for the current generation and even more for future generations.

CHAIRMAN STETKAR: Anything else?

Again, Ed, thanks a lot. We appreciate your input, and we have certainly considered it and will.

That's everything that was actually on our agenda for this afternoon. Surprisingly enough, we've finished the presentations much ahead of our schedule. Unless any of the members have any lingering questions for any of the presenters, what I'd like to do is we always do, in Subcommittee meetings, I'd like to go around the table and get any final comments that the members might have.

Oh, yes, I forgot. Thank you. What we'll do first is I'll ask if there's anyone in the room who would like to make additional comments. We'll also get the bridgeline opened up so that members of the public who have been patiently waiting out there and listening in will have the opportunity to do that before we go around the table for the remainder of the member comments.

Anyone in the room? If not, we'll just wait until we get the bridgeline open. People are waving at me as if the bridgeline is open, but I don't believe them because I've not heard. That's an interesting sound, different than normal. There we go. It sounds like the bridgeline is open.

Someone please just do us a favor and say hello so that we confirm that it's open.

MR. BUDNITZ: This is Bob Budnitz. Can you hear me?

CHAIRMAN STETKAR: Yes, Bob, thanks. So we know it's open. Now, if there's anyone on the bridgeline who would like to make a comment, please identify yourself and do so. Anyone?

MS. GILMORE: Hello?

CHAIRMAN STETKAR: Yes.

MS. GILMORE: Yes, this is Donna Gilmore. I missed the first part of the meeting. Is it out of scope to talk about the issues related to the waste storage for this meeting? Is that for another time?

CHAIRMAN STETKAR: You're allowed to make comments on any topic, as long as we're -- we're addressing the concept of societal risk, so I'd like to keep it away from a particular facility, if that's where your comments are headed. But we'd be happy to hear --

MS. GILMORE: I read a 2000 letter that Dana Powers had written about the risk to the pool from high burn-up fuel creating oxides, hydrides, that could cause some potential explosion if any of the spent fuel was exposed to air. My question relates to dry storage because I've been trying to find out exactly what will happen with a through-wall crack in dry storage. And depending on what will happen will determine, you know, the risk that you're talking about.

So my specific question is, if there's a through-wall crack in a dry storage canister and with a high burn-up fuel, and I know that the oxides increase as the burn-up increases, and if air gets in there, what will be the impact and has there been any analysis done on this issue? Could there be an explosion? Has there been any research done on this?

CHAIRMAN STETKAR: We don't normally, it's dangerous for us in the Subcommittee meetings to try to answer questions realtime. I believe that issue has been addressed. I'm not sure specifically for high burn-up fuels but certainly analyses have been performed for dry cask storage.

If you would like to contact our staff, they can help to point you to publically-available results of those analyses. As I said, right off the top of my head, I'm not conversant enough with those analyses to know whether they've specifically addressed high burn-up fuels. But if you contact John Lai or Mike Snodderly of our staff and John Lai's email -- well, you have our phone number, so just call the ACRS. Okay.

MS. GILMORE: I've seen the low burn-up. I haven't seen anything on the high burn-up.

CHAIRMAN STETKAR: Okay. And as I said, I don't know what's been done on high burn-up, but, if there's something available, we can certainly point you in the direction of that.

MS. GILMORE: Okay, thank you.

CHAIRMAN STETKAR: You're welcome. Anything -- are there any other members of the public who'd like to make a comment?

MR. LEWIS: Marvin Lewis. Look, it's not even a comment. It's real simple. I've been trying to look up SOARCA. It was mentioned real early in the program, and anybody want to tell me what SOARCA means?

CHAIRMAN STETKAR: Yes. It's the State of the Art Reactor Consequence Analysis.

MR. LEWIS: Thank you.

CHAIRMAN STETKAR: You're welcome. Anything else? Any other members of the public?

MR. VECCHIARELLI: Hello, this is Jack Vecchiarelli from Ontario Power Generation.

CHAIRMAN STETKAR: Hi.

MR. VECCHIARELLI: Yes, hello. Just at a high level, I just would like to say that this whole discussion is of great interest here in Canada and we do have quite a lot of work ongoing within the Canadian industry around whole-site risk and safety goals. And the notion that was discussed earlier about large release frequency, for us, that does serve a dual purpose in terms of limiting health risk, as well as serving to limit the potential for long-term relocation.

So I'd just like to say it's a very good discussion and that we are very actively working on various concepts in this area.

CHAIRMAN STETKAR: Thank you very much. I'm sorry. I know we had quite a few discussions trying to get someone from either your organization or someone from Canada to give us a briefing at this meeting, and I guess, you know, logistics fell apart. So I'm glad that --

MR. VECCHIARELLI: That would be me. I'm sorry I was not able to attend, but I've been listening to most of the discussion today.

CHAIRMAN STETKAR: Great, thank you. Any other comments from the public? Going, going, gone. Thank you very much. We will silence the bridgeline so that it stops popping and crackling in our ears. And now I'll take the opportunity, unless there's something else I forgot. I'm getting old. Now I'll take the opportunity to go around the table for any -- I'll ask the members two things: first, if you have any final comments; and a bit more difficult in this particular instance of whether the Subcommittee feels that the topic should be brought to the full Committee because that's part of what we do in the Subcommittee is determine whether something should be brought to the full Committee. And because I always start with Joy, I'll start with Harold.

MEMBER RAY: Thank you, John. Well, I think this was a very important topic, and one thing you've heard me say -- thanks so much. It's a very important topic, and one thing you've heard me say at other times and I do believe it is that societal risk varies at different sites. And we saw some data today that illustrated that. And for that reason, I tend to think that plants that are located in areas with very low societal risk should not necessarily have to meet the same requirements as those located in areas of high societal risk do. So that's an element that I think is of interest and worth pursuing.

More broadly, the question of what's included and what's excluded from the definition of risk and what societal costs consists of, it's certainly a discussion around which I don't think there's every any definitive answer and simply policymakers have to decide what's in it and what's out because it's a discussion that has no end.

As far as going to the full Committee is concerned, as usual, I would think that's only if we think it's timely for a letter to be developed or it may be so. That's for the Committee to decide, of course. And I don't know enough about the status here to say I think it is time or we ought to wait until more takes place before going to the full Committee and potentially sending a letter out to either the DDO or the Commission. I just don't know on that. It might be time.

As I say, it doesn't lack for importance in my mind, but we have to allow time to further develop some of the issues that were discussed here today, and there are many of them. So that's the best I can do, John, in terms of --

CHAIRMAN STETKAR: Would you, Harold, just to make sure I understand, would you advocate another Subcommittee meeting to try to flesh out more details before it went to the full Committee or not?

MEMBER RAY: Well, you know, there are different views that were expressed here today, and so I don't know that we can mediate those, John, if we could pursue more detail with any one of the presenters. But I think the real question is where's our staff on this and what's the likelihood that it is timely from the standpoint of the Commission policymakers, and I just don't know.

CHAIRMAN STETKAR: Okay, thank you. Steve?

MEMBER SCHULTZ: I'll start with where Harold left off I think, and that is perhaps the best way for us to interact with the staff on this is to play off the notions that were presented by today and, in particular, the connection between what was discussed and then Bob Budnitz's comments associated with what might be done by Nuclear Regulatory Research.

One of my concerns is that without policy and without direction what seems to be happening associated with the consequence evaluation, you know, trying to broaden that out for current reactors or for future reactors is that we're taking kind of a sidelight approach. We don't have the focus of a program of the scope that Dr. Budnitz suggested. And I think really, rather than the sidelight, I think we really need a headlight focus that we might wind up with if we had some discussions with Research, most appropriate, I think, first by the Subcommittee but then perhaps bring that to the full Committee after some thought by the Subcommittee and have the full Committee react to or make a recommendation on what type of research might be done in this area.

My other comment is that there's certainly a connection between the discussion on the health consequences with regard to radiological releases for latent cancer fatalities and then the evaluations and the decision-making that goes into relocation and permanent re-entry, and that is something that, I mean, we simply answer by saying, well, we can't change the pegs, and so don't go in that direction. And maybe that's true, but one of the ways that's been approached in the past is perhaps not to change it but to try to recognize what the conservatives might be in those pegs and try to make that at least part of the thought process, if not part of the decision-making information that's used to move forward with these decisions. Thank you.

CHAIRMAN STETKAR: Thank you, Steve. Mike?

MEMBER CORRADINI: So I would agree with Steve that I think, based on what we've heard today, that, at the very least, Research should undertake some sort of more direct look at alternatives to societal risk goal than we currently have. What form that study takes I think, though, pretty much depends on resources allocated.

The one thing that came to my mind is I'm not exactly sure where this might fit into the Level 3 study, which seems, to me, to be the logical place I would start to try to investigate it relative to the analyses they're doing there. But I do think that I agree with Bob Budnitz that at least we should attempt to see if we can retrospectively look at things such that we can prospectively predict, so I think the way he stated it in his slides I think I would very much agree with. At the very least, we should try to do that.

But I don't think it's time for a letter. I think we should try to get somebody to generate a user need -- and if we're the ones that generate it, so be it -- so that we get some sort of activity in research.

CHAIRMAN STETKAR: Yes. The way, you know, subcommittees don't generate user needs.

MEMBER CORRADINI: I'm not even sure ACRS does.

MEMBER SCHULTZ: Perhaps the full Committee could.

CHAIRMAN STETKAR: The full Committee can write a letter and make, you know, the Commission, DDO's office, whoever, aware of our position on something. That's all we can do. I mean, you know. Dennis?

MEMBER BLEY: Yes. I really appreciated all the presentations and discussion today. Two things. First, there's a much, there seems to be a very nice clean case and maybe several alternatives for identifying how one would go at setting a safety goal for societal risk at the high level. How you make that operational in terms of an actual societal objective is may be more difficult than I had expected, but I haven't thought a lot about this in a long time.

This is really an important issue, I think. And I'd like to see us go to a full Committee. Now, whether we write a letter or we put something very strong in our research report or what we do, the idea that was brought up by one of the presenters and Mike or Steve earlier that we provide some urging that the Level 3 PRA look at alternatives for dealing with societal risk I think is a good one and maybe that's the guts of a letter.

But I think the full Committee ought to hear about this. We ought to discuss it and decide what to do next.

Another Subcommittee, you know, several of us were at the workshop that was discussed and a lot of ideas passed around then. We've seen many of them come back, some refined. I'm not sure what we've put together for a subcommittee, so I'm not leaning that way right now. But maybe we'd find more. If we found more work that would be interesting to follow, that might be a good idea.

But I don't know what that is at this point.

CHAIRMAN STETKAR: Thank you. Ron?

MEMBER BALLINGER: Yes. I think this is a very important issue, and I think I agree with Steve and Harold. It's kind of a nebulous issue, too, in the sense that we have to really get it right. So I think we should move forward in a very deliberate way, and the research idea is a good way to go, I think, and the Level 3 is a good vehicle in which to embed something like this.

I'm not sure how you'd generate a user need, if you will, or a description of how to proceed. Maybe it's not a user need. Anyway, I think we need to do something. Whether it's a subcommittee, I think I agree with Dennis, I'm not sure we need a subcommittee. But I think we eventually do need to go to the full Committee.

CHAIRMAN STETKAR: Joy?

MEMBER REMPE: Well, I disagree, I guess. First of all, I'd like to thank everybody who came and talked to us today and gave their opinions and the status of their work on it. I know some of them have been doing it on their own times, and I think it was great that they were willing to come and share their thoughts. But I think we do need another subcommittee before we even make the recommendation to put it into the Level 3 PRA because I'm not sure if you said to do this with the Level 3 PRA, but they've got the models. I mean, I think we need to think through what we're asking before we would go tell them to start trying to do something in the Level 3 PRA work.

I was most interested in the gentleman, I wish I could have asked the gentleman who called in from Ontario about the status of their work and practical implementation of it. So that's why I think we need to have another Subcommittee meeting so we could proceed in a deliberate manner and see what is practical to ask for and not ask for before we make recommendations to the staff because resources are limited. And maybe you and others who have been participating in this workshop and have been following the area, I do have a better idea that, from my perspective, I wouldn't know of a good practical recommendation to make to this staff on this area unless we heard a little bit more about it. So that's where I'm at.

CHAIRMAN STETKAR: Thank you. I'd like to thank very much all of the presenters. I also feel that this is a very important topic personally, and I'm happy that we could actually pull this all together and get everyone to discuss it and very much appreciate all the effort everyone put into their presentations and getting here and all of that trouble.

I'm kind of torn regarding whether we should go to the full Committee or not. My initial inclination is that a full Committee briefing would be worthwhile. The full Committee could then decide whether or not a letter is warranted and what that letter might entail. For the life of me, I can't think of what the second part might be at the moment, but that's not the purpose of the Subcommittee meeting.

The other alternative that we have is we do have a Level 3 PRA subcommittee meeting scheduled already for January. It's only half a day, and we're planning to talk about this. That meeting might give us an opportunity to, at least at the subcommittee level, broach the notion with them because they, in fact, have said in the past, I went back and looked this up in some of my notes, that, indeed, they plan to look beyond health effects in their consequence analysis. They haven't quite told us what they plan to do, but it might give us an opportunity, at least in January, to get a little better sense of what the staff is planning to do. And that may or may not influence whether or not we bring this particular topic to the full Committee.

MEMBER REMPE: Could we possibly have -- apparently, you did try and talk to the person from Ontario. Could we have some update on that at this time?

CHAIRMAN STETKAR: Not at the Level 3. The problem is we already have topics set up for -- I don't know whether we could expand it to a full day is the problem.

MEMBER REMPE: Even a half-hour or an hour presentation or something from them, just something so we have a little more -- this might be a practical thing that you could do with your existing models is where I'm at.

CHAIRMAN STETKAR: It might be. We could probably try to explore that. I'm just a little concerned on the time constraints that we have in January for the meeting. We can look into it. I mean, we did try, we were kind of on again/off again with the Canadian folks to see whether or not they could actually come and present. And I don't know, I've read some of the stuff that they've put together, but the stuff that I've seen is pretty high level. I mean, it's a concept.

So that might be something that we can explore in the January time frame. Again, I have no idea whether anyone from Canada could actually support that meeting, but we could try.

So I guess, I don't know, I'm hearing kind of not clear whether we should -- if we bring it to the full Committee, it wouldn't be until probably the March time frame anyway. I mean, we can certainly decide in January.

MEMBER BLEY: We'll have had that meeting on the Level 3.

CHAIRMAN STETKAR: Level 3 research folks --

MEMBER BLEY: Are you expecting them to talk about things beyond health effects in that --

CHAIRMAN STETKAR: At the current, the preliminary information that they were going to discuss doesn't address this topic at all.

MEMBER BLEY: But they have raised it in the past.

CHAIRMAN STETKAR: But they have raised it in the past. I mean, it's our subcommittee. We can ask them to address issues if they have the wherewithal to do that. And I'll take it, you know, as the Subcommittee Chairman, I'll take it up with John Lai or Mike Snodderly since John is going to be gone most of December to broach the notion with the staff and also to see whether anyone from Canada could support that meeting.

If you're listening in from Canada, I'm not trying to put you on the hook. Just be aware of the warning shot being fired across your bow. Look, it's warmer here than it is in Canada.

MEMBER REMPE: Well, if the lines work well, you could send slides.

CHAIRMAN STETKAR: Yes, that's right. I mean, you could always give it remotely.

So let's leave it that way. We'll try to get this topic at least as part of our discussion on the January Subcommittee meeting agenda with the staff on the Level 3 PRA and see where the Subcommittee decides to take it from there regarding bringing it to the full Committee.

MEMBER BLEY: Well, let's put it on P&P for February and we can --

CHAIRMAN STETKAR: Yes, that's good. Yes, yes, let's do that, let's do that. Anything else from any of the members? If not, thank you all and we are adjourned.

(Whereupon, the above-referenced matter went off the record at 2:37 p.m.)

Current NRC QHOs and Societal Risks of Severe Accidents in Perspective

Presentation to ACRS Subcommittee on Societal Safety Goal
December 1, 2015

Vinod Mubayi
Brookhaven National Laboratory

Current NRC Safety Goals - QHOs

- Limiting individual health risk from ionizing radiation released in accidents has been at the core of NRC safety goal policy
- The Quantitative Health Objectives (QHOs) limit individual risks of early fatality and latent cancer in the population residing near a plant to a small fraction (0.1%) of an appropriate background risk

Current Safety Goals – Societal Risk

- Societal risk is addressed in the safety goal policy in two ways:
- Risks of nuclear power generation should be comparable to or less than other technologies for generating power
- Nuclear power should not be a significant contributor to other societal risks
- However societal risk itself is not defined

Experience with current safety goals

- QHOs have been estimated in a number of Level 3 PRAs
- NUREG-1150 plants satisfied QHOs by wide margins taking into account uncertainty (although most addressed internal events only)
- More recent studies, e.g. SOARCA, reach same conclusion by even wider margins
- Actual accidents, TMI-2 (minor release) and Fukushima (major release), also satisfy QHOs
- Even Chernobyl likely satisfies QHOs

Fukushima Accident Consequences

- > 20,000 died due to drowning by tsunami
- QHOs were satisfied even without factoring in release probability
  - Zero early fatality due to acute radiation exposure
  - No measurable increase in latent cancers expected
- Huge societal impact of Fukushima
  - Long-term relocation of ~ 100,000 people
  - Cost of recovery estimated > $ 76 billion

Societal Risk

- By adopting risk acceptance criteria based on QHOs alone are we addressing relevant risks?
- Society expends significant resources on protecting people from radiation exposure. How far should it go?
- Protective actions involve long-term disruption of people’s lives with multi-factorial impacts and huge costs
- To derive a societal goal look at other events that have a similar large societal impact

Assessment of societal risk

- Natural phenomena, hurricanes, earthquakes, floods, have consequences similar to NPP accidents: large-scale evacuation, maybe some fatalities, huge damage, large cleanup and remediation costs
- Various risk metrics, e.g. number of people evacuated and relocated, etc., can be considered to assess the disruption caused by natural events, but many can be subsumed in a common metric such as cost
- Hurricanes can be considered as one option, among others, of background risk to which NPP accidents can be compared
- A database of hurricane severity and cost has been compiled by Roger Pielke and associates at U. Colorado
- Costs (updated to 2012$) of destructive hurricanes and severe accidents at a (NUREG-1150 study) NPP (Zion) are shown in following tables

Table I: Normalized Damage Costs of the Most Costly Hurricanes 1900-2012

Rank	Hurricane	Year	State	Category	Costs (2012 US$ billion)
1	Greater Miami	1926	FL, AL	4-3	185
2	Katrina	2005	LA, MS	3	151*
3	Galveston	1900	TX	4	92.0
4	Galveston	1915	TX	4	72.8
5	Sandy	2012	East Coast	3	67*
6	New England	1938	CT, MA, NY, RI	3	46.3
7	11	1944	FL	3	45.7
8	Andrew	1992	FL-LA	5-3	45*
9	Lake Okeechobee	1928	FL	4	39.6
10	Donna	1960	FL-NC, NY	4-3	34.9
11	Ike	2008	TX-LA	2	33
12	Ivan	2004	AL-FL	3	26*
13	Camille	1969	LA, MS	5	25.0
14	Betsy	1965	FL-LA	3-3	24.4
15	Wilma	2005	FL	3	23*
16	Rita	2005	FL-AL-MS	3	22
17	Charley	2004	FL	4	21
18	Agnes	1972	FL-CT, NY	1-1	20.7
19	Diane	1955	NC	1	20.3
20	4	1947	FL-LA, MS	4-3	19.8
21	Hazel	1954	NC, SC	4	19.5
22	Charley	2004	FL	4	19.2
23	Carol	1954	CT, NY, RI	3	19.0
24	Hugo	1989	SC	4	17*

Source: Reference 15 augmented by data from Reference 16 identified with asterisk.

Table II: Zion Offsite Damage Costs at 100 Miles

Scenario	Frequency (per Yr)	Offsite Cost ($2012)	Scenario	Frequency (per Yr)	Offsite Cost ($2012)
1	7.50E-08	1.06E+09	12	2.30E-07	3.33E+10
2	1.10E-06	1.30E+09	13	8.10E-07	4.26E+10
3	1.60E-07	3.04E+09	14	1.40E-07	4.93E+10
4	9.70E-08	3.40E+09	15	4.70E-08	5.35E+10
5	1.00E-07	6.85E+09	16	2.90E-07	5.77E+10
6	6.50E-07	9.56E+09	17	6.00E-08	5.90E+10
7	3.80E-08	1.07E+10	18	4.90E-08	6.65E+10
8	2.20E-07	1.87E+10	19	4.70E-08	7.59E+10
9	2.90E-08	1.99E+10	20	2.60E-08	8.54E+10
10	4.20E-08	2.57E+10	21	3.20E-07	8.69E+10
11	4.70E-07	2.87E+10	22	1.20E-08	9.77E+10

Source: Reference [19]; Costs in 1990 dollars were updated to 2012 dollars.

Calculations carried out using the MACCS code, offsite costs are likely underestimated by a significant factor due mainly to old decontamination cost model in the code

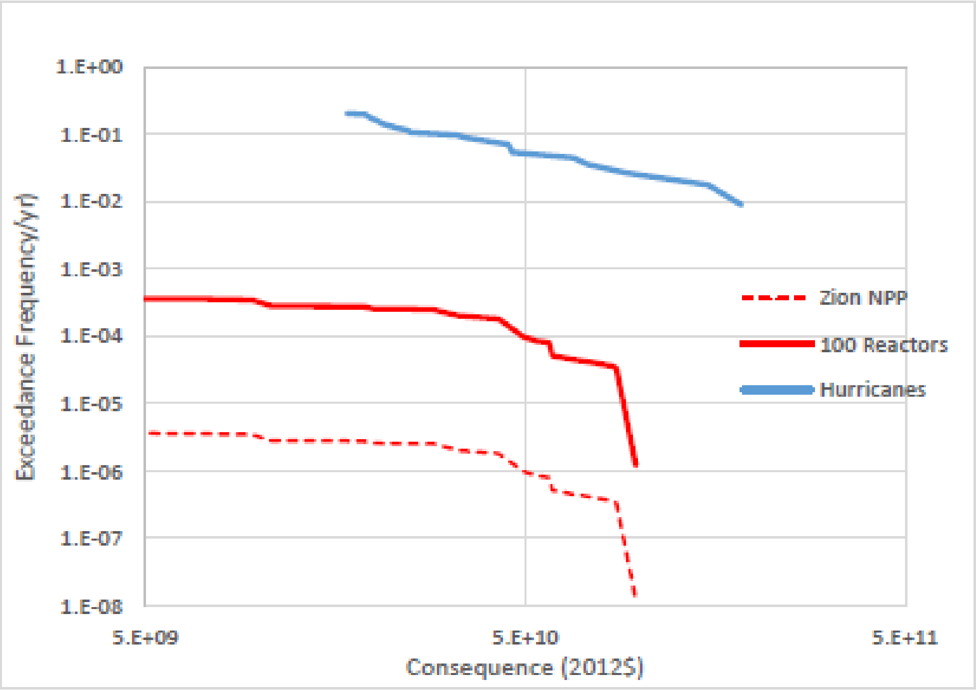


Figure 1. A Comparison of Hurricane and Nuclear Power Plant Risks

Societal risk of hurricanes and NPPs

- Mean societal (cost) risk of Zion NPP over all accidents is \$1.5E+05 per year: small compared to mean societal risk of \$9.5E+09 per year from hurricanes in U.S.
- If costs increased by a factor of ~ 6 (based on Fukushima), still 4 orders of magnitude margin
- Single NPP cost risk would meet a 0.1% risk goal compared with hurricanes as background risk
- If Zion risk was extended to all 100 U.S. plants, total NPP risk would still be < hurricane risk but more difficult to meet a 0.1% goal
- CCDF trends based on figures in the tables are shown in the figure

Concluding Remarks

- The last time NRC staff substantively considered NPP societal risk seems to be in the 1999-2001 period
- SECY-99-191, SECY 00-0077, and SECY-01-0009 tentatively addressed societal risk but only in terms of radiation dose/health effects
- Clearly, a new approach is needed
- In 1968, NRC defined an “extraordinary nuclear occurrence” (ENO) and codified it in 10 CFR 140 in terms of both dose (140.84) and cost (140.85) impacts
- While the numbers do not appear to reflect costs of severe NPP accidents, the statute itself may be a vehicle for introducing a notion of societal risk in cost terms

Insights into the Societal Risk of Nuclear Power Plant Accidents

Richard S. Denning

ACRS PRA Subcommittee
Meeting December 1, 2015

Impacts of Fukushima

- The meltdown of three of the Fukushima Dai-ichi reactors as the result of a massive tsunami has had a major impact on Japanese society and on the Japanese economy, in ways that were not fully anticipated.
- Response to the accident has substantially changed public perception, public policy, and reactor regulation world-wide.
- And yet, the radiological impact of the accident on human health is and will be small (as confirmed by the World Health Organization and UNSCEAR).

Change in Risk Perspective

- We have historically placed inappropriate emphasis on the health risk to the public from nuclear power plant accidents and inadequately addressed the societal impact of extensive land contamination.
- Human health risk from nuclear power plant accidents is extremely small.
- The principal risk is associated with the societal impact of land contamination.

NRC Safety Goal Policy Statement

1). Individual members of the public should be provided a level of protection from the consequences of nuclear power plant operation such that individuals bear <u>no significant</u> additional risk of life and health,

2). Societal risk to life and health from nuclear power plant operation should <u>not be a significant addition</u> to other societal risk, and

3). Societal risk to life and health from nuclear power plant operation should be <u>comparable to or less</u> than the risks of generating electricity by viable competing alternative technologies.

Quantitative Health Objectives

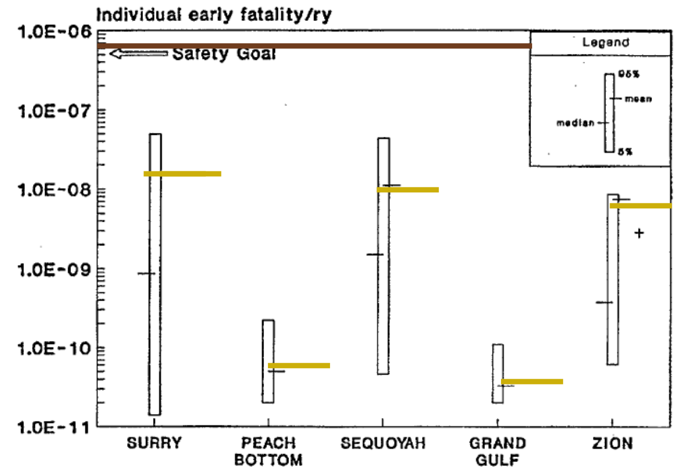
QHOs – Relate to health risk objectives.

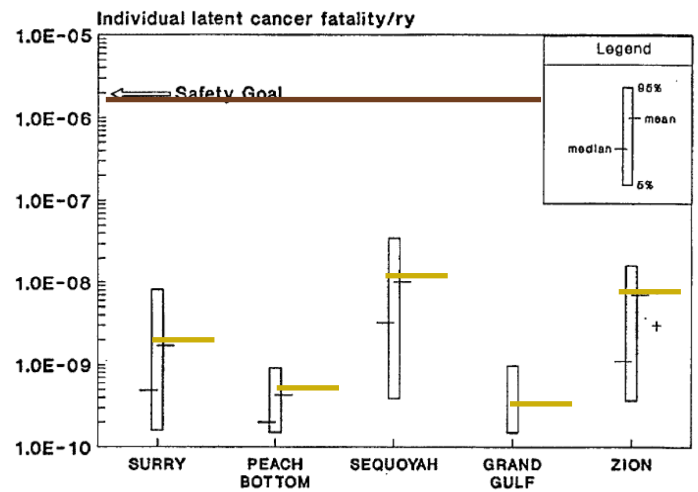
1). The risk to an average individual in the vicinity of a nuclear power plant of prompt fatality that might result from reactor accidents should not exceed one-tenth of one percent of the sum of prompt fatality risk resulting from other accidents to which members of the U.S. population are generally exposed.

2). The risk to the population in the area near a nuclear power plant of cancer fatalities that might result from nuclear power plant operation should not exceed one-tenth of one percent of the sum of cancer fatality risk resulting from all other causes.

NUREG-1150 Risk Perspective

- Risk to someone living in the near proximity to a nuclear power plant is not significant
- No aspect of the Fukushima accident would change that perspective
- SOARCA study indicates that NUREG-1150 has over-estimated offsite consequences





Comments on QHOs

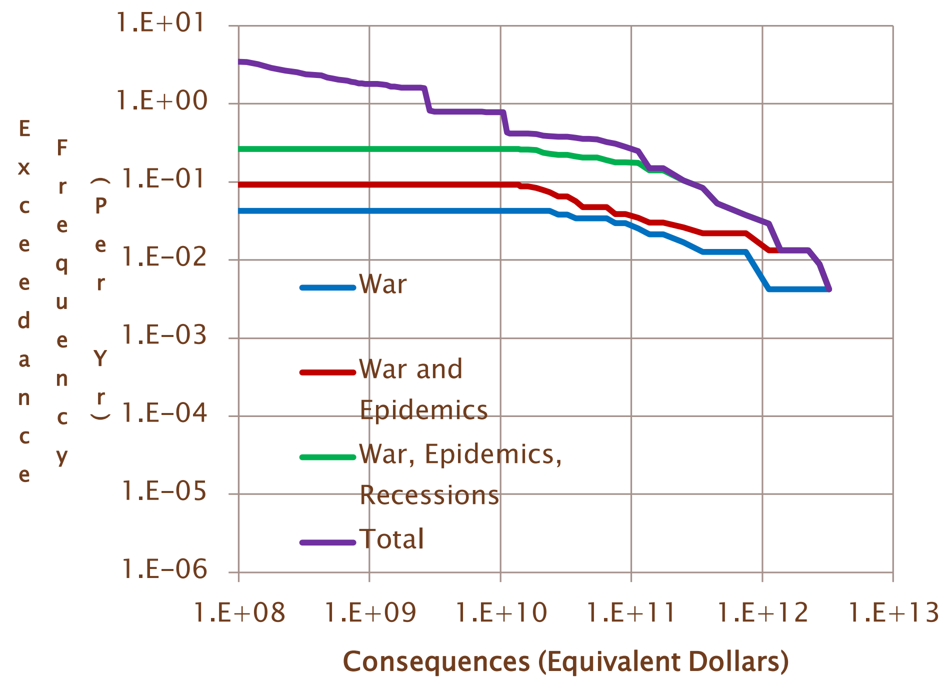
- Early fatality goal is referred to as the individual health risk goal
- Latent cancer fatality goal is referred to as the societal risk goal
  - But it isn’t societal risk
  - It is calculated on a per individual basis
  - It is just a different form of individual health risk
- Fukushima makes it clear what constitutes societal risk
  - Land contamination, relocation, loss of production
- If we established quantitative societal objectives what would they look like?

QSO: Comparison with Other Societal Risks

- Two approaches can be used to compare societal risks
  - Compare the expectation value of the probability density function – the most commonly used measure of risk (probability times consequences)
  - Complementary cumulative distribution function (CCDF) – frequency with which a given level of consequence is exceeded.
- The CCDF is particularly appropriate characterization of societal risk because the concern is for very large events that can be societally disruptive.

Monetized U.S. Societal Risks

- Non-nuclear events – reconstructed from U.S. data ($5 million per life)
- Wars, epidemics, recessions – very large consequences
- Remainder are:
  - Floods
  - Earthquakes
  - Droughts
  - Mine explosions
  - Aircraft, trains
  - Fires
  - Tornadoes
  - Hurricanes



Perspective on Societal Risks

- Based on U.S. historical data, the risk from catastrophic events does not have a major impact on our society.
  - Individuals are impacted.
  - Mean risk of the societal risk from large events curve is $\$1.2 \times 10^{11}$/yr (compared to GDP of $\$1.5 \times 10^{15}$/yr) or \$380/yr per person
- But the curve only reflects what has happened historically not what could happen.
- The potential certainly exists for a war or epidemic that killed a significant fraction of the U.S. population.
  - Wars, epidemics and famine are the major risks that can dramatically affect society.

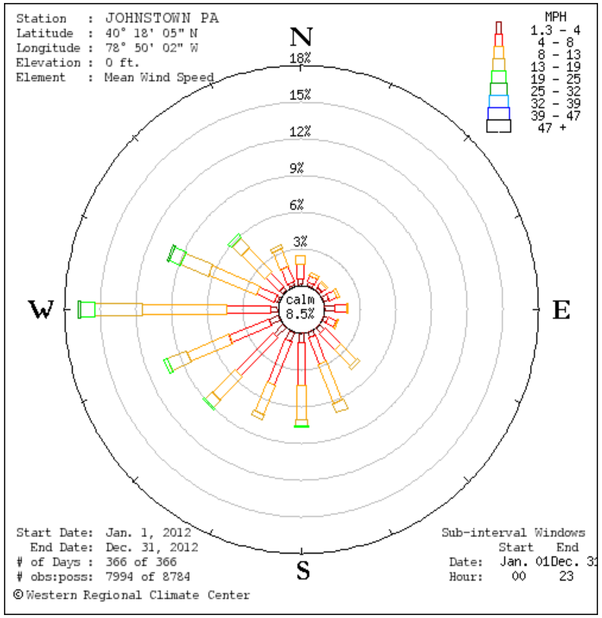
Model of U.S. NPP Societal Risk

- Simple model of 104 U.S. plants developed using NUREG-1150 conditional containment failure mode probabilities but SOARCA-based source terms.
- Only four core melt scenarios required:
  - Short-term station blackout – PWR
  - Short-term station blackout – BWR
  - Bypass event (interfacing systems LOCA)
  - Core melt but no containment failure

Mode	Composite CF Probability	Release Fraction Cesium
Bypass	4.2E-3	0.1
Early Contain Fail	0.34	0.02
Late Contain Fail	0.14	0.007
No Contain Fail	0.52	0

Societal Risk Based on Area of Land Contamination

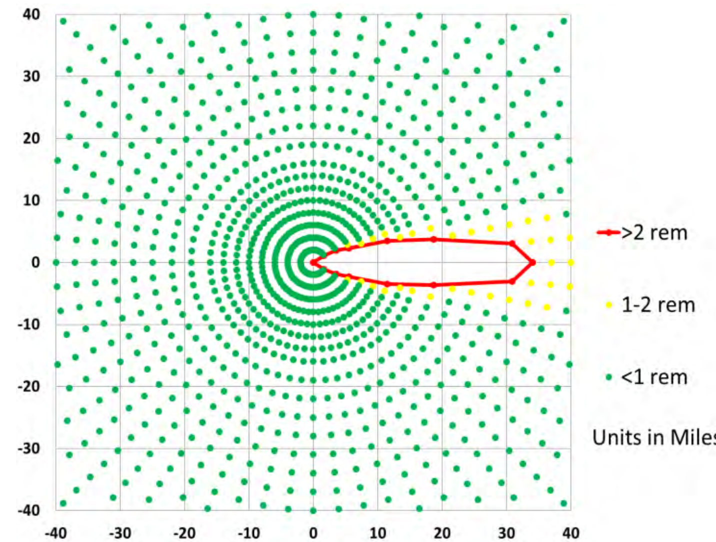
- For each scenario, area of contamination determined that would result in a first year dose of 2 rem based on ground shine from deposited ^{134}Cs and ^{137}Cs.
- Four actual U.S. sites used with wind rose site specific.
- Identical annual meteorologies based on one actual site.



Case	P-G Class	Wind Speed (mph)	Probability
1	A	3	0.28
2	D	4	0.44
3	D	15	0.07
4	F	4	0.21

Model of U.S. NPP Societal Risk

- Analyses performed with WIN-MACCS computer code – earlier analyses performed with RASCAL were limited to 50 miles.
  - Insufficient to capture large events.



- Uncertainty bounds for core damage frequency for 104 plants
  - Low: $1.0*10^{-5}$ per yr – PRA results for best U.S. plants
  - High: $3.3*10^{-4}$ per yr – Non-believer in PRA based on world data for core damage in LWRs

Scenario Consequences

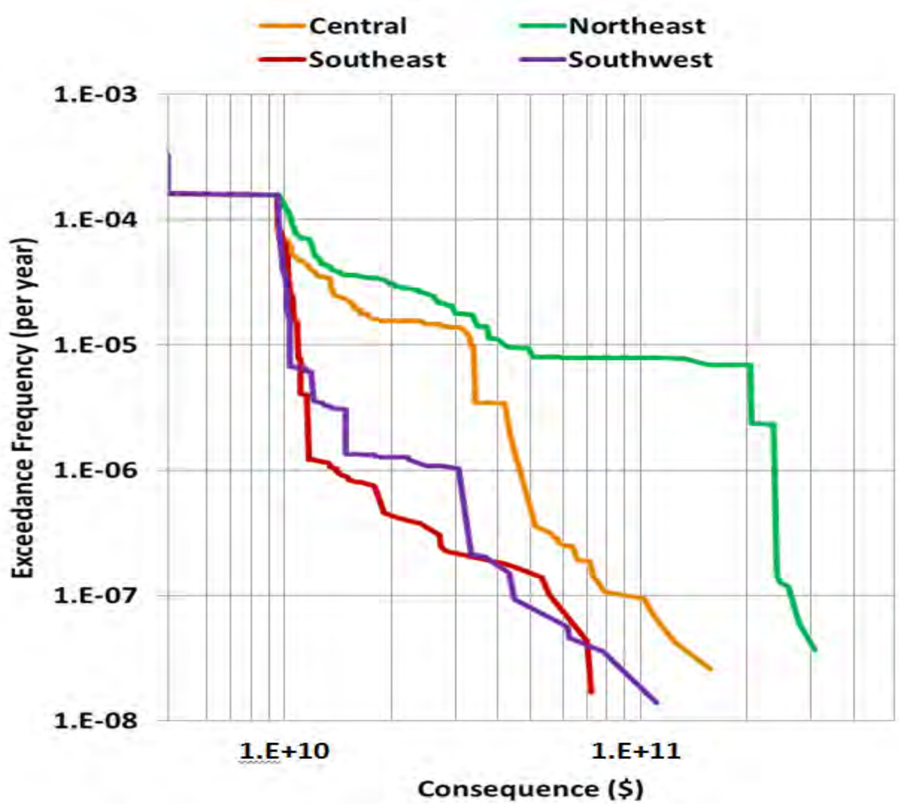
- Industrial and agricultural production totaled based on percentage of each ZIP code within relocation area
- $10 billion added to scenarios with containment failure, based on Chernobyl data
- $5 billion added to the case with core damage but no containment failure, based on TMI cleanup data
- $4,000/person relocated, based on FEMA's relocation reimbursement
- Decontamination costs determined by population density rather than land area – based on actual bids for decontamination projects in Japan.

Cases Considered

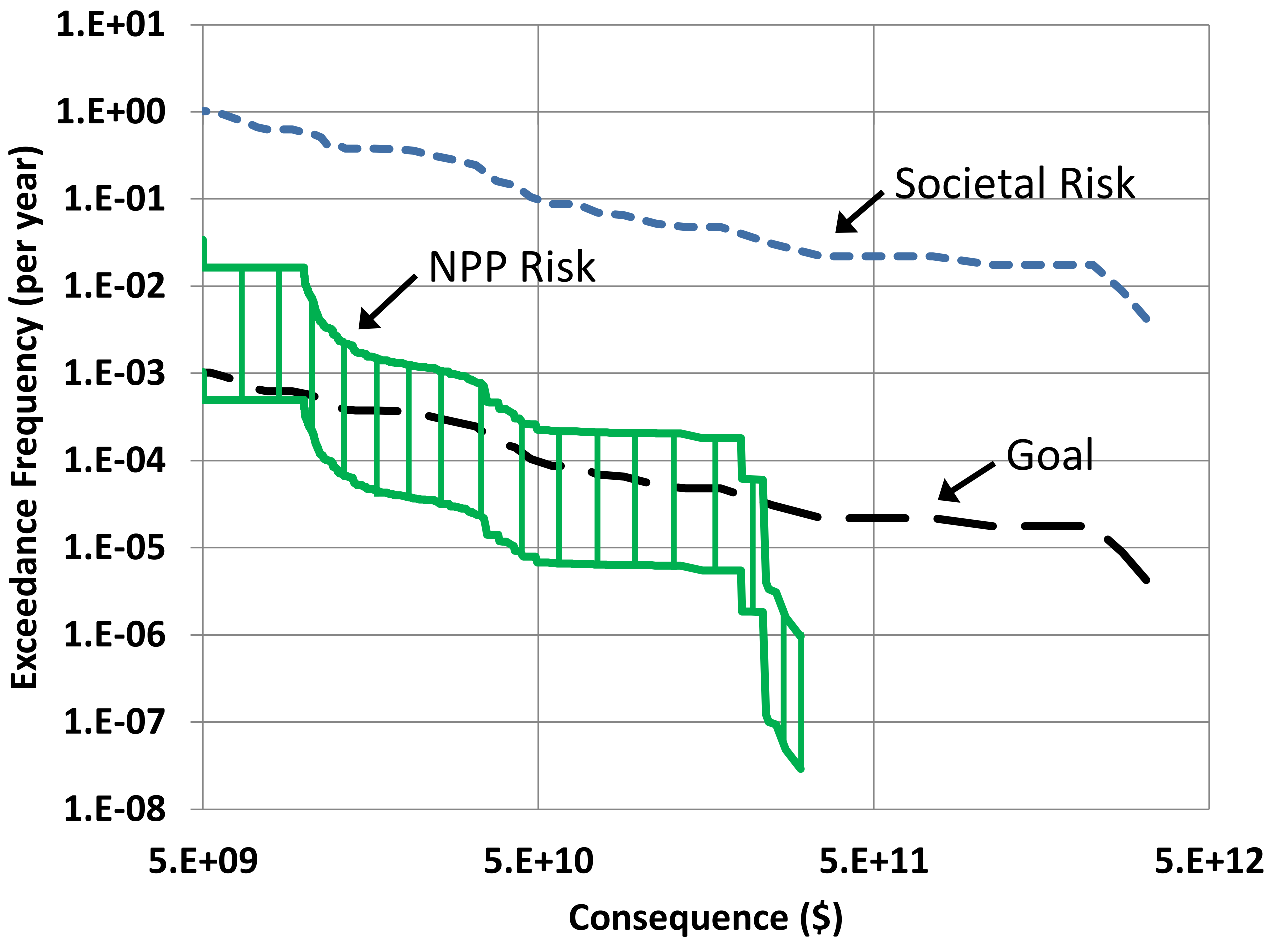
- NRC has not developed a quantitative goal for societal risk
  - In the spirit of the QHOs, NPP results are compared with 0.1% of the background risk curve
- NPP results calculated for 4 cases:
  - No decontamination cost
  - Low decontamination cost
  - High estimate of decontamination
  - Multiplier of 2.5, based on “>1 rem” relocation area
- Risk curves only reflect uncertainty in core damage frequency – there are other substantial uncertainties.

Comparison of Risk Curves – Four Sites

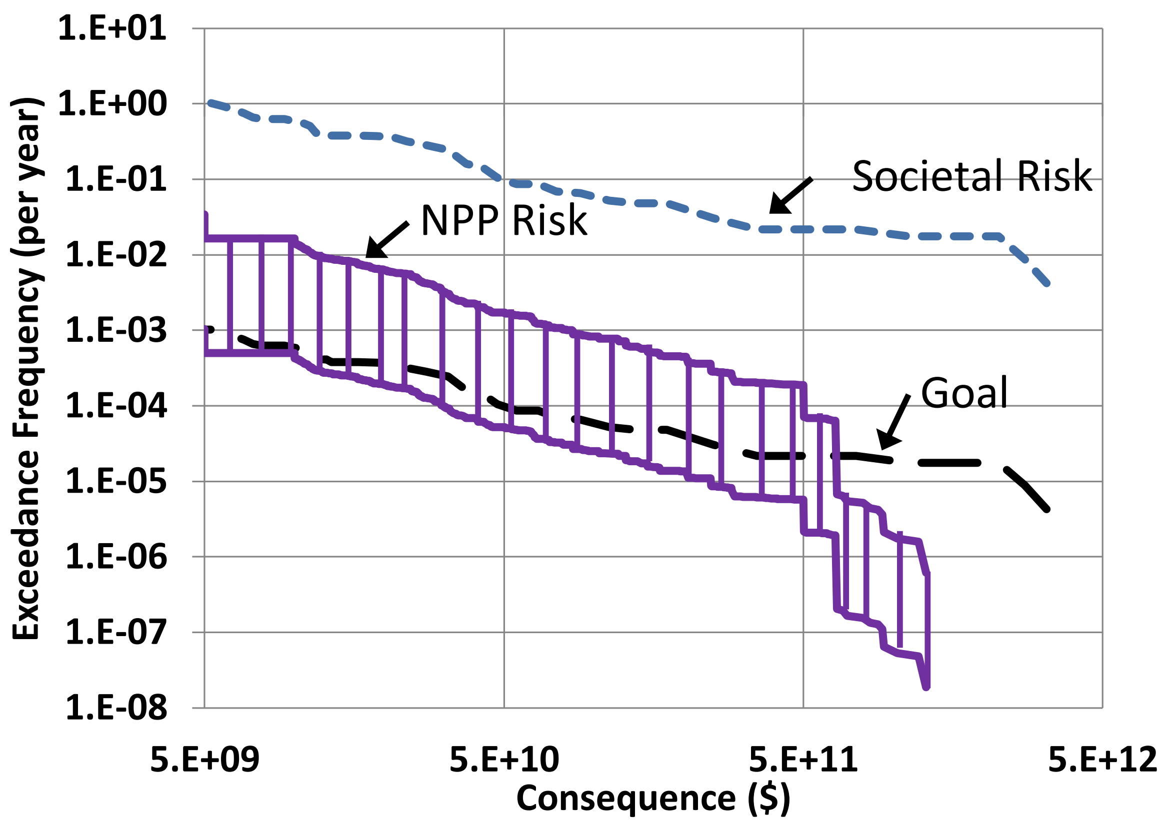
- The societal risk associated with a nuclear power plant accident is very site dependent.



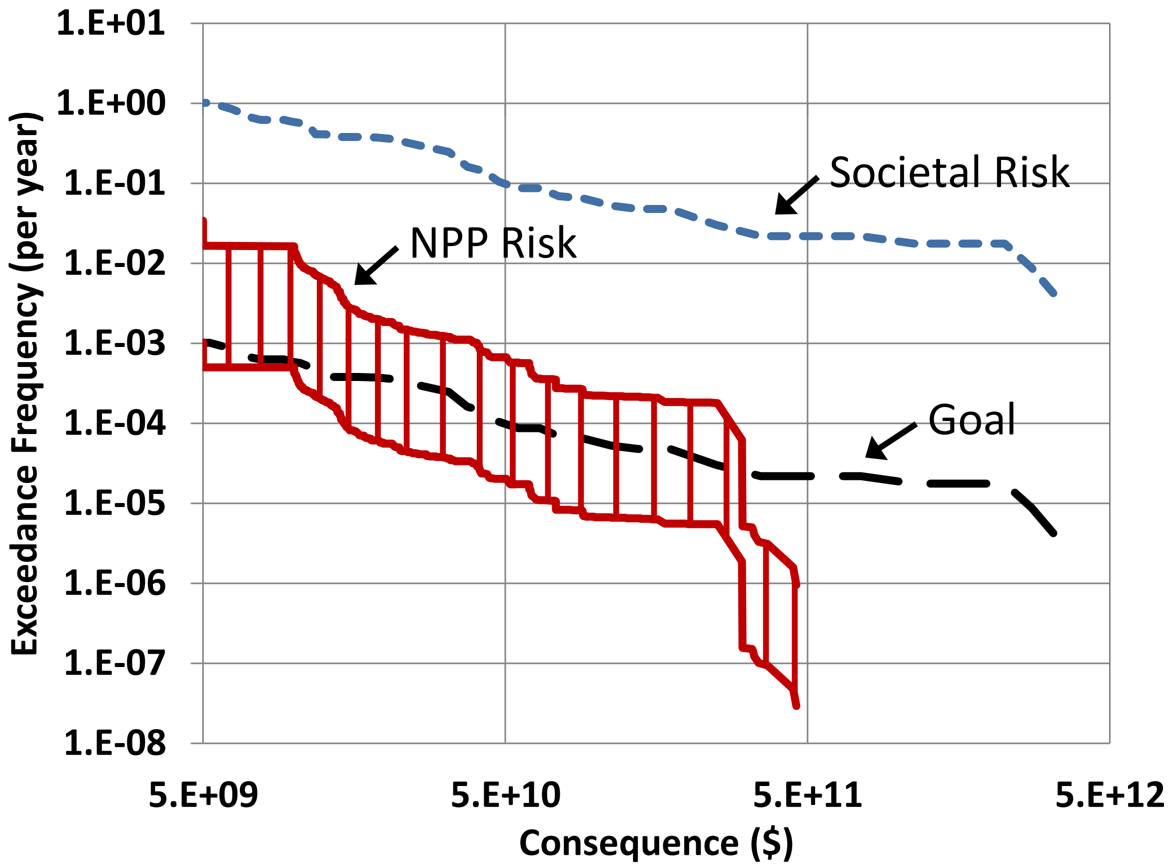
Societal Risk – No Decon Cost



Societal Risk – High Decon Cost



Societal Risk – Low Decon Cost



Comparison of Risks and Benefits

- Mean risk for three cases
  - Base case: 1.0×10^{7} – 3.3×10^{8} dollars/yr
  - High decon: 1.9×10^{7} – 6.3×10^{8} dollars/yr
  - 1 rem relocation: 1.3×10^{7} – 4.4×10^{8} dollars/yr
- On a per capita basis these values represent small risks.
- Although high population sites have higher risk, the risks are less than four times the above values.
- In a world with global warming, an impending major fresh water crisis, continued loss of arable land area and the need to find a replacement for fossil fuel, we need to develop more risk-informed criteria for the siting and regulation of nuclear power plants.

DEPARTMENT OF Engineering Physics
College of Engineering University of Wisconsin-Madison

Modeling Societal Disruption from Nuclear Accidents to Inform Regulatory Decision-Making

Vicki Bier, Mike Corradini, Caleb Roh, Shuji Liu
UW-Madison

Robert Youngblood
Idaho National Laboratory (INL)

Work supported through the INL National Universities Consortium (NUC) Program under DOE Idaho Operations Office Contract DE-AC07-05ID14517.

Safety Goals

- Existing NRC safety goals have long been recognized as narrowly scoped:
  - Focus on dose to individuals
  - Don't explicitly address aggregate societal impacts (therefore not a true societal-risk goal?)
  - Don't explicitly address disruption
  - Don't account for social determinants of health (e.g., stress-induced deaths)

Safety Goals

- Qualitative goal:
  - Societal risks to life and health from nuclear power plant operation should be comparable to or less than the risks of generating electricity by viable competing technologies and should not be a significant addition to other societal risks
- Quantitative goal:
  - The risk to the population in the area of a nuclear power plant of cancer fatalities that might result from nuclear power plant operation should not exceed 0.1 percent of the sum of cancer fatality risks resulting from all other causes
  - Normalized by population! Doesn't constrain societal risk…

Objective of Our Work

- Our objective was to evaluate social disruption from severe accidents as a basis for developing a societal-risk goal:
  - Considerations could include both health effects, and non-health concerns like property damage and land interdiction

Motivation

D E P A R T M E N T O F **Engineering Physics**
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- Current goals do not have a societal-risk component:
  - Don't constrain number of cancer fatalities from an accident
- Current focus on radiological risks leaves a gap in addressing:
  - Health risks due to evacuation
  - Costs of clean-up, decontamination, and relocation
  - Loss of communities
  - Loss of land for crops and industrial activities
  - Inability to sell contaminated foods
  - Loss of freshwater resources
  - Loss of income
  - Need for replacement electric power
  - Psychological issues ("relocation trauma," stigma effects)
- Societal disruption could be as important as health risk:
  - Number of people relocated is a proxy for societal disruption

Analysis: Reactors Considered

- 3 pressurized water reactors, 2 boiling water reactors
- Chosen to represent a variety of:
  - Sites (seashore, river, lakeshore, inland)
  - Regions (Eastern, Southern, Midwestern)
  - Population densities (< 25,000 to > 400,000 within 20 miles)
- Representative of reactors in the U.S.:
  - Sites were not chosen to represent a "worst case"

Analysis: Accident Scenarios

- Long-term station blackout (LTSBO):
  - Loss of offsite power and diesels (DC batteries operational)
- Short-term station blackout (STSBO):
  - But DC batteries assumed unavailable (more severe)
- STSBO with steam-generator tube rupture (SGTR):
  - Containment bypass with early release (PWR)
- LTSBO, no reactor-core isolation cooling (RCIC) (BWR)
- Interfacing-system loss-of-coolant accident not considered (much more severe but of much smaller probability than others)
- Used source terms for ***unmitigated releases*** from State-of-the-Art Reactor Consequence Analyses

Analysis: Weather Conditions

- Actual weather in effect on each of 24 different dates:
  - Near the middle of each month in 2011 and 2012
- Assumed start time of the accident chosen randomly:
  - To ensure a variety of atmospheric conditions.
- Data from nearest station of National Weather Service:
  - 10-40 miles distance from the plants used
  - Wind direction and speed, temperature, and precipitation
- Hourly quality-controlled local climate data, or:
  - One-minute data, Automated Surface-Observing System
- Stability class and mixing-layer depth:
  - From the NOAA Air Resources Laboratory

Analysis: Dispersion Modeling

- Radiological Assessment System for Consequence Analysis
  - RASCAL compares reasonably w MACCS (NUREG/CR-6358)
- The 2D plume model in RASCAL uses only surface-weather data:
  - Compares favorably with the 3D models in Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT)
- Constructed a source term for each accident scenario:
  - Similar to State-of-the-Art Reactor Consequence Analyses
- Timing did not match well for BWR scenarios:
  - RASCAL assumes earlier release times (more severe)
  - But within an order of magnitude for all accident scenarios

RASCAL Validation – Dispersion

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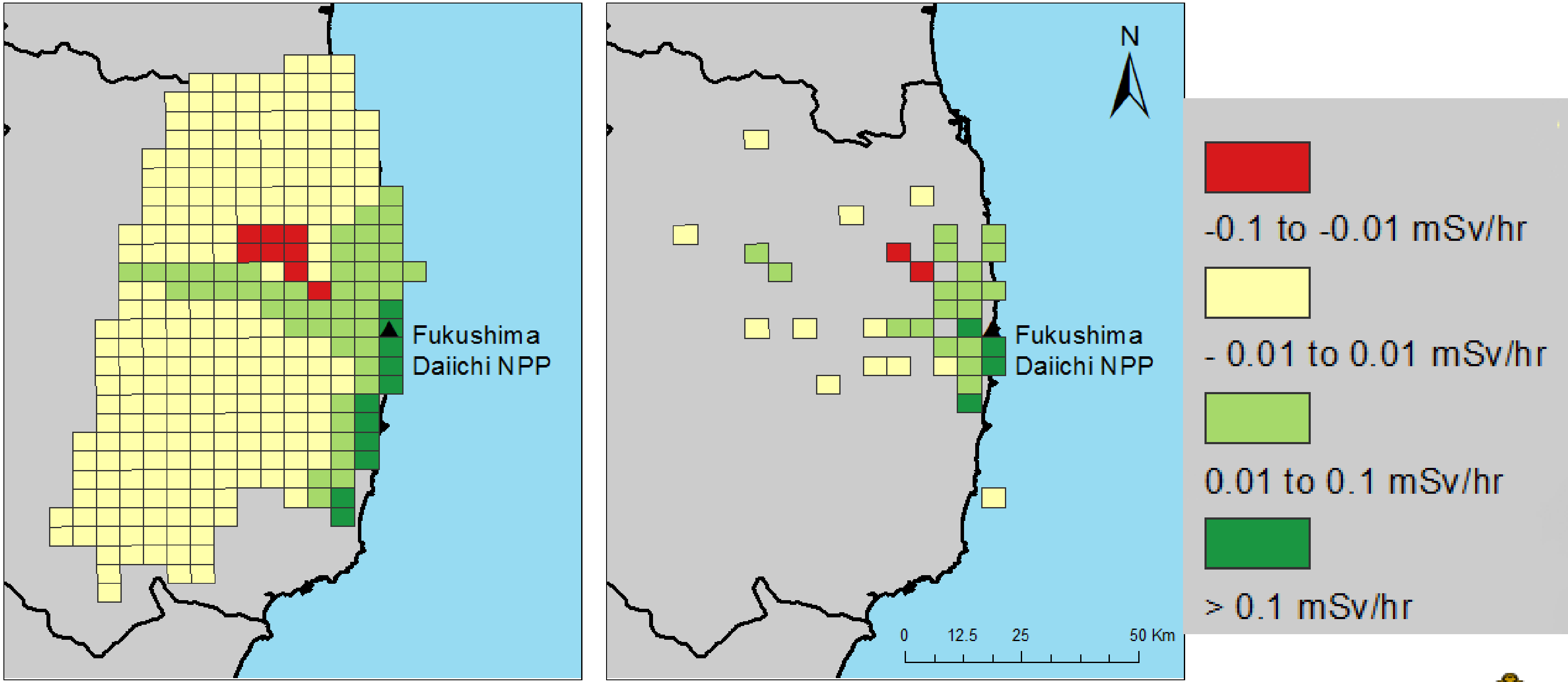
- RASCAL simulation compared to observed data:
  - Green area indicates area where dose is overestimated
  - This is reasonable, since RASCAL is conservative



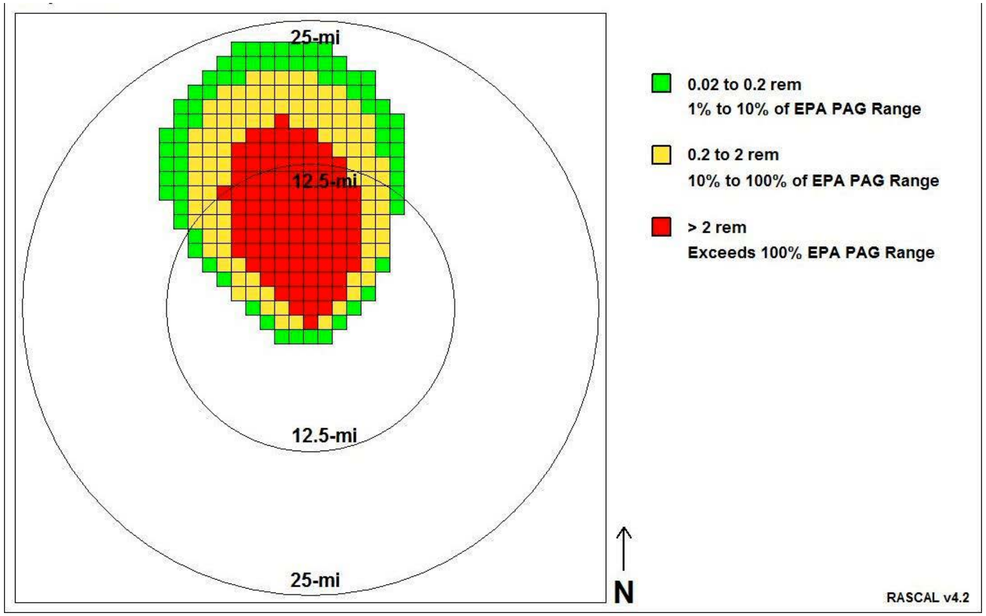
Exposure Differences RASCAL Predicted - DOE Observed (Avg.)

Exposure Differences RASCAL Predicted - Srinivas et al. Observed

(Hammond, 2013: Plumes based on actual weather conditions)

Analysis: Geographic Data

- Dose profiles exported as geospatial "shape files":
  - Total effective dose equivalent for a year after the accident



- **Red:** doses exceed the 2-rem protective-action guideline
- **Yellow:** 0.2-2 rem in one year
- **Green:** 0.02-0.2 rem in one year (out to 25 miles)

Results: People Relocated

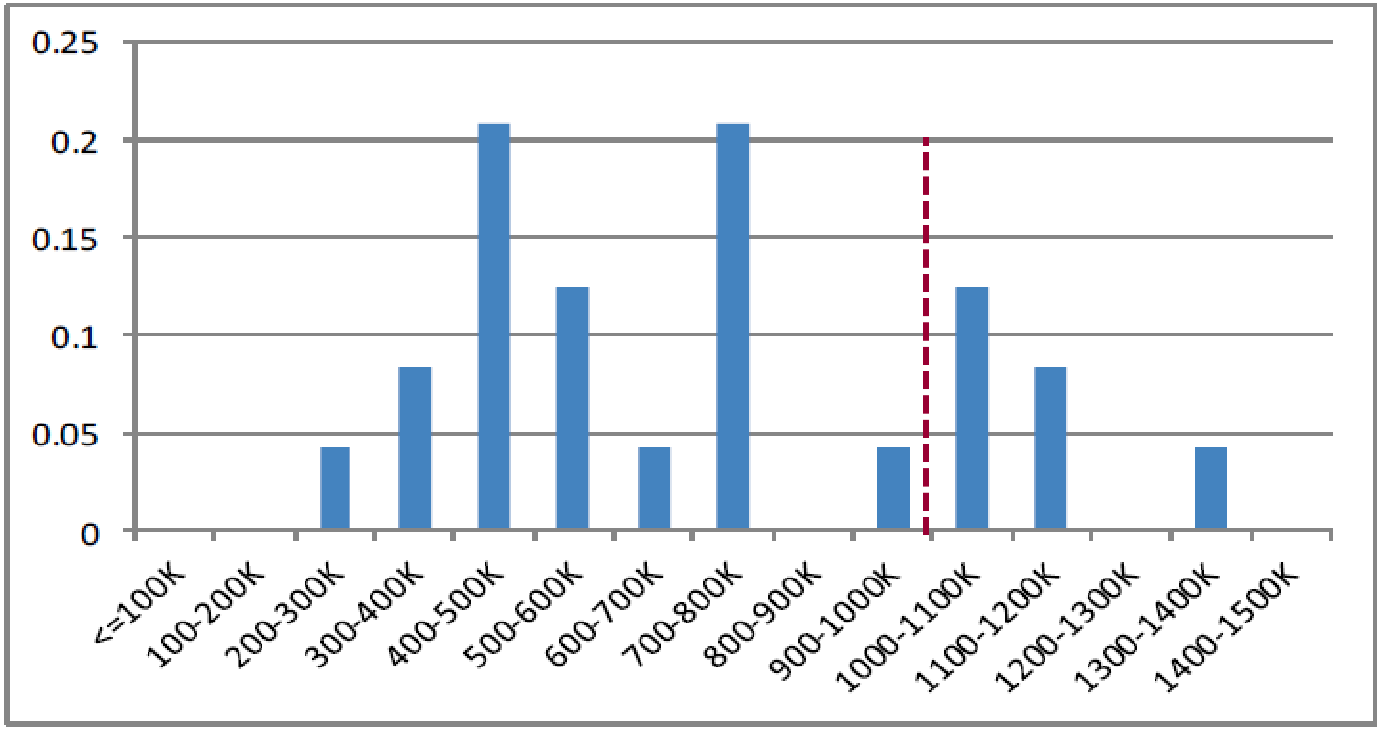
- 90% confidence intervals:
  - Based on one-year, 2-rem protective-action guideline

Plant	STSBO	LTSBO	STSBO w/ SGTR	LTSBO w/out RCIC
A (Eastern seashore)	30,000-400,000	0-20,000	300,000-1,000,000	
B (Midwestern inland)	8,000-200,000	0-10,000	40,000-500,000	
C (Midwest lakeshore)	20-30,000	0-300	200-100,000	
D (Eastern river)	0-60,000	0-70,000		0-80,000
E (Southern inland)	0-70	0-60		0-80

- From State-of-the-Art Reactor Consequence Analyses

Results: Weather Variability

- Highly dependent on weather conditions



- For the most severe case, large relocations are not rare:
  - 25% of relocations involve more than 1 million people

Results: Weather Variability

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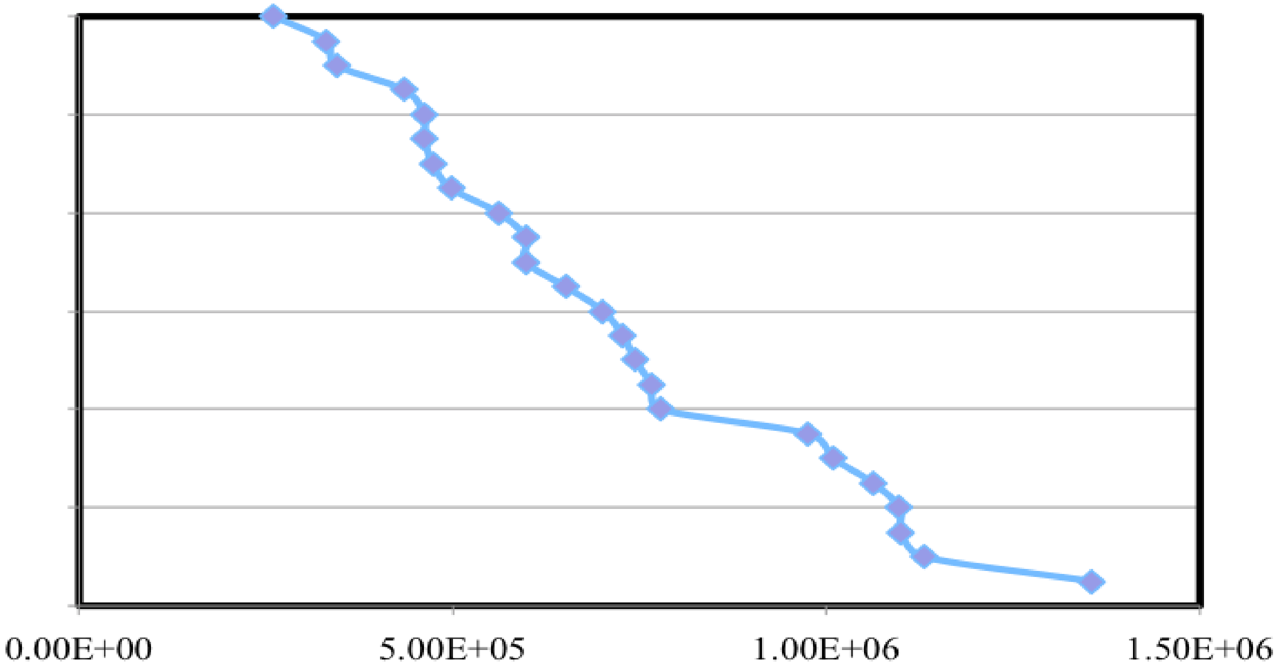
- Complementary cumulative distributions also show this



- Large relocations due to unfavorable wind direction

Results: Weather Variability

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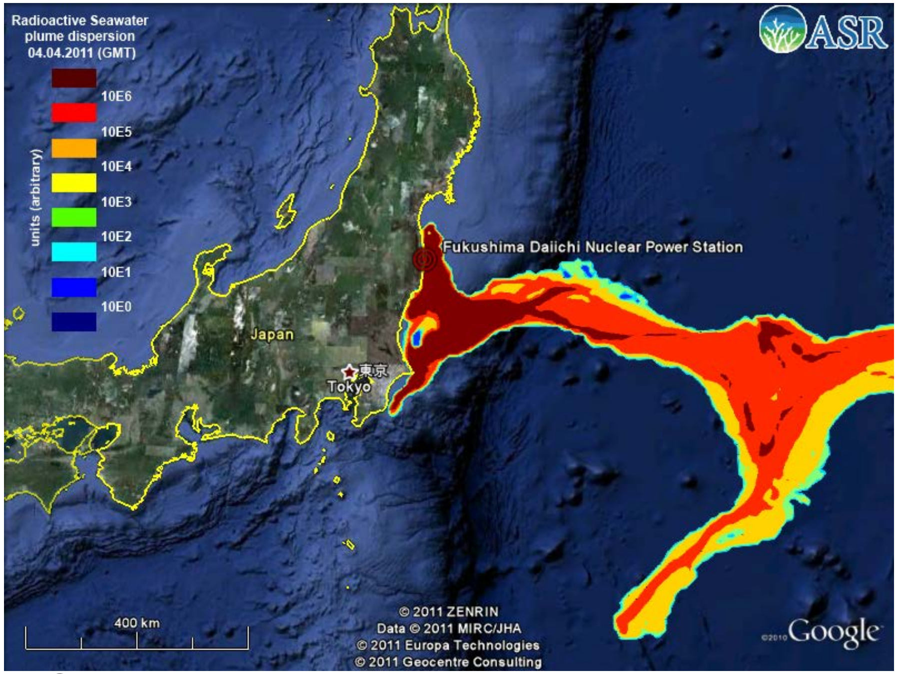
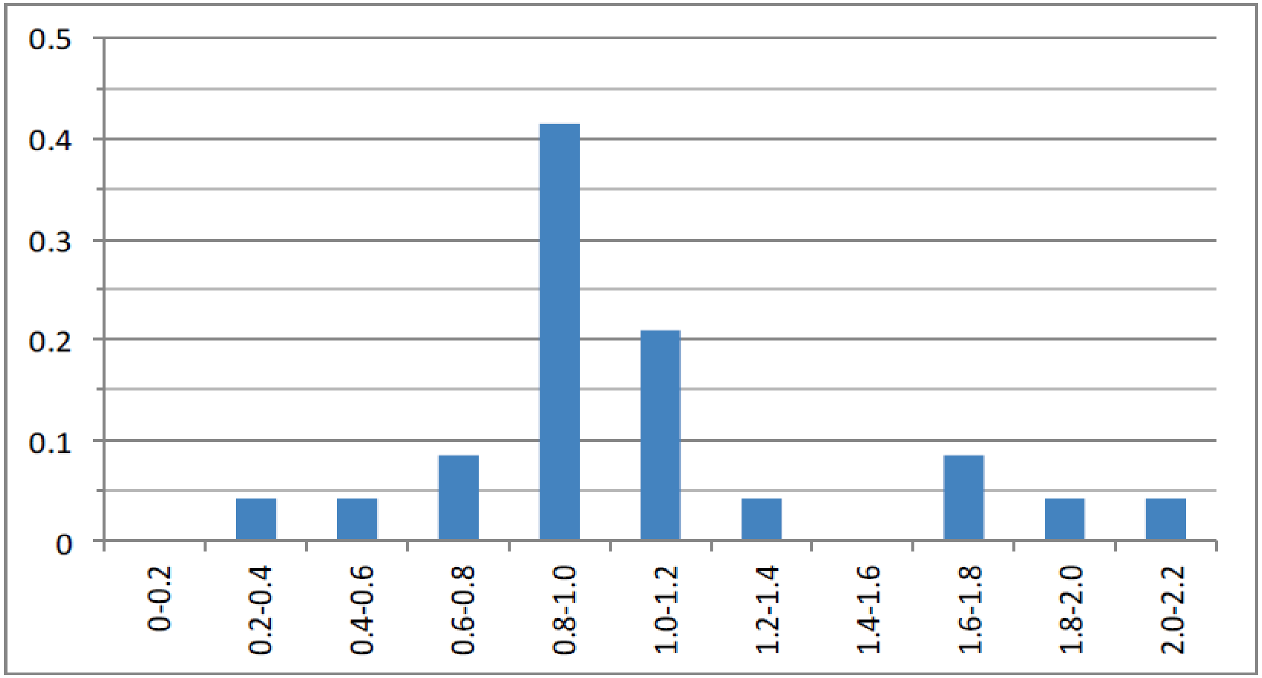
- Results in Japan could have been much worse



- Even with a favorable wind direction:
  - 100,000-500,000 people evacuated/relocated
  - 100,000-200,000 have not returned home four years later
  - ≤3,000 died due to stress (survey by Asahi Shimbun)

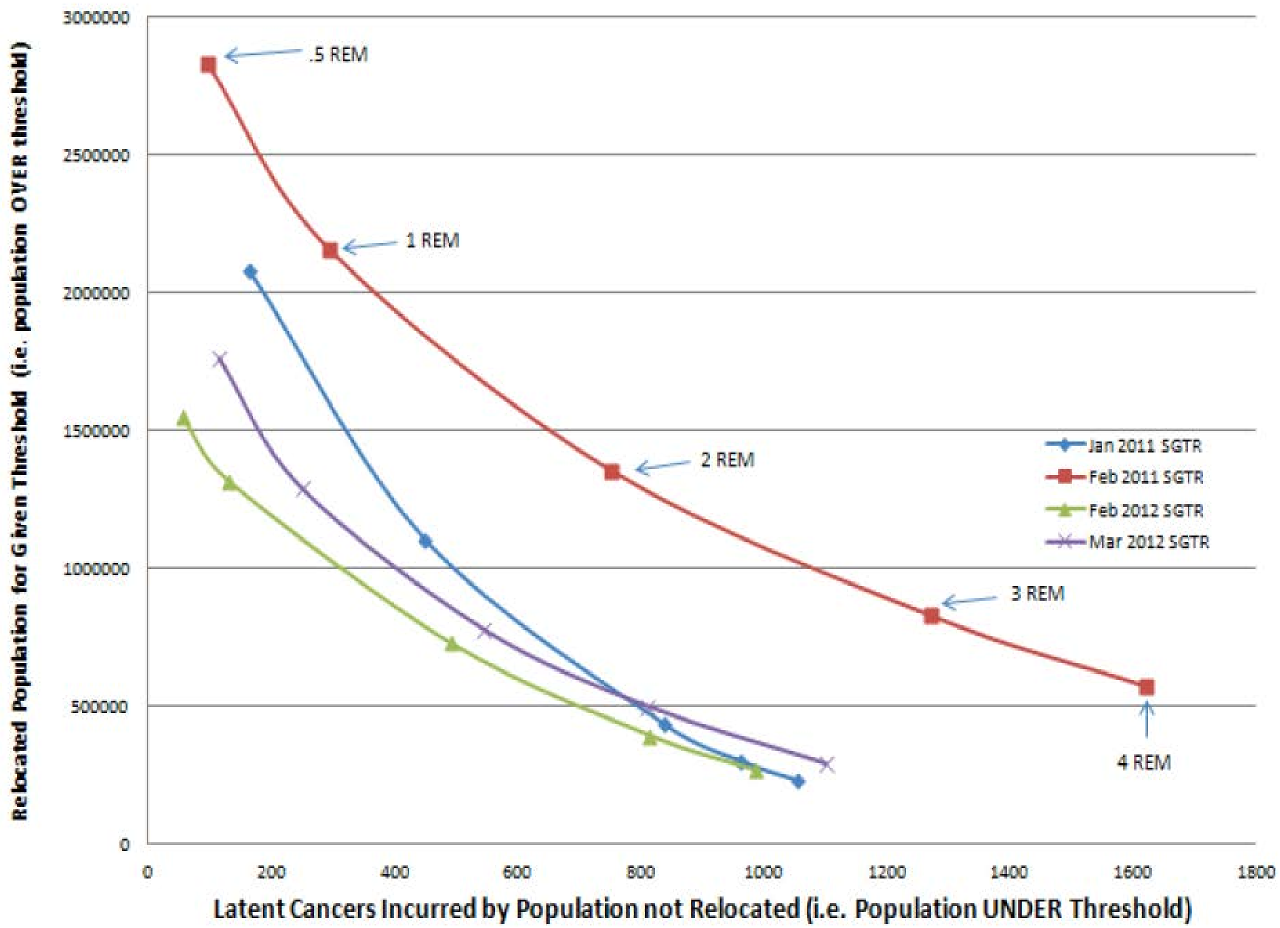
Results: Long-Term Relocation

- Unfortunately, return to normal may not be rapid:
  - Based on experience in Japan and Chernobyl
- Long-term relocation areas are not always smaller:
  - Based on 50-year protective-action guideline of 5 rem
  - Because dose is accumulated over such a long time



Results: Alternate Guidelines

Consider smaller relocations (based on less conservative guidelines)



Results: Alternate Guidelines

- Increasing protective-action threshold above 2 rem:
  - Would reduce the number of people relocated
  - While increasing the number of latent cancer fatalities
- Preventing one cancer fatality may require relocating 800 people!
  - Even more, if "linear no-threshold" overestimates fatalities
- Benefits of reduced disruption would be immediate:
  - While increased cancer fatalities would not occur for years

Conclusions/Recommendations

- Number of people relocated is a proxy for disruption:
  - Objective, health-based, and straightforward to calculate
- It is in principle possible to meet almost any cancer goal:
  - Just by relocating enough people!
- Safety goals should consider societal disruption:
  - E.g., weighted sum of fatalities and relocation
  - E(cancer fatalities) + 1/λ E(relocations) ≤ Bound
  - Parameter λ expresses weight given to relocation (e.g., based on $2000 per person-rem and cost of relocation)
- Such a goal would constrain aggregate cancer fatalities:
  - Without implicitly rewarding extensive/excessive relocation
  - And could provide guidance for siting of advanced reactors

Conclusions/Recommendations

- Goal could also reflect risk aversion for large relocations:
  - Suggested by Starr (1976), Griesmeyer and Okrent (1981)
  - Not needed for cancer fatalities, since they are distributed over space and time
  - E(cancer fatalities) + $1/\lambda$ E(relocations$^{\beta}$) $\leq$ Bound
- Combination of constraint on aggregate cancer fatalities, together with exponent for risk aversion, suggests that additional precautions may be needed at populous sites

Summary / Next Steps

- The technical work has led to the expected results:
  - Costs of societal disruption can be huge
  - Those costs are not reflected in existing practice
- The work lends itself not only to revision of safety goals:
  - But also to reconsidering how safety goals are applied in regulatory analysis, which may be more feasible
- Further work could include:
  - Quantifying proposed safety goal, consistent with modern understanding of societal determinants of health
  - Extending regulatory analysis to consider preventing large societal disruption as "substantial safety enhancement"

Backup Slide

Sensitivity: Dispersion Modeling

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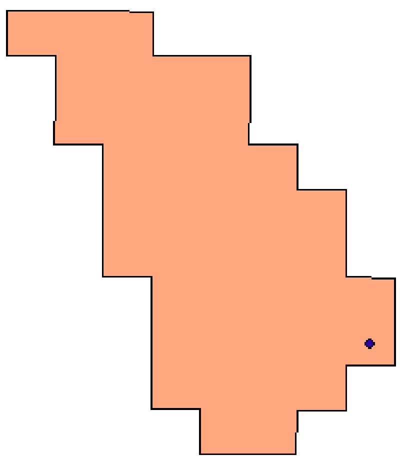
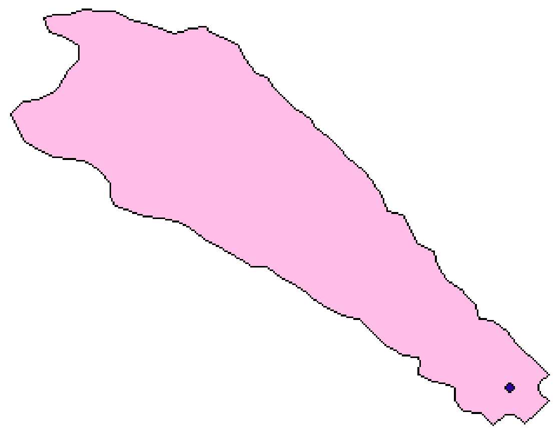
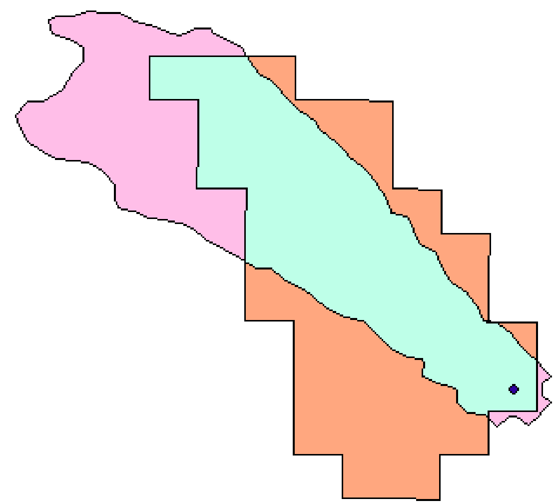
RASCAL Plume



HYSPLIT Plume



Area of Overlap



(Blue Area Only)

$$\textit{Ratio of Overlap to RASCAL} = \frac{\textit{Blue Area}}{\textit{Orange Area}} = 0.55$$

$$\textit{Ratio of Overlap to HYSPLIT} = \frac{\textit{Blue Area}}{\textit{Pink Area}} = 0.64$$

(Hammond, 2013: Plumes based on actual weather conditions)

EXTERNAL EVENTS AND SOCIETAL RISK --- WHY MIGHT THESE NEED TO BE TREATED DIFFERENTLY IN ANY "SOCIETAL SAFETY GOAL" POLICY ?

1 December 2015, Rockville MD

Presentation before the ACRS subcommittee meeting on "societal safety goals"

Robert J. Budnitz

Energy Geosciences Division
Lawrence Berkeley National Laboratory
University of California
Berkeley CA 94720 USA
<RJBudnitz @ LBL.gov>

What is needed to support formulation of a "societal safety goal"?

- Formulating a "societal safety goal" requires analysis of the various non-human-health impacts:
  - property damage (radiological)
  - economic disruption (both radiological and non-rad.)
  - non-economic disruption (households, the "community", the "social fabric," etc.

(some sort of "expected value" of consequences over a range of accident scenarios)

(perhaps a distribution capturing our state-of-knowledge of the consequences as a function of annual frequency)

Distinctions

- **First distinction: A large external-hazard event (earthquake, hurricane, etc.) can cause important offsite impacts in the absence of an NPP. Some of these impacts are similar to those caused by an NPP accident.**

- **Second distinction: Some vital emergency protective measures, both on-site and offsite, may be very different!**

  (An example might be "evacuation" vs. "relocation.")

- **Third distinction: Emergency protective measures, both on-site and offsite, may be much more difficult to implement in the presence of a large external-hazard event (earthquake, hurricane, etc.)**

Questions

- **After the event (the hurricane, earthquake, etc.), and after the NPP accident, is it "easy," "difficult," or "impossible" to distinguish the NPP-caused impacts from the non-NPP-caused impacts?**

- **Looking back – (say, to the Fukushima scenario), is it feasible to distinguish these?**

- **If not, performing prospective analysis is also not feasible.**

- **CRUCIALLY: Without a useful analysis, a "societal safety goal" tied to these impact end-points could not be implemented!**

My bottom line

- **I am convinced that the NRC's authority extends to a concern for the impacts other than the radiological-health impacts of NPP accidents.**
- **I am convinced that in some major external-hazard events, 2 types of non-radiological-health impacts will occur: (a) those due to the ext. hazard itself, and (b) those due to the NPP accident.**
- **I am convinced that it is feasible to distinguish which-is-which (even given the uncertainties.)**

My bottom line (continued)

- **I am convinced:**

  - that the NRC needs to undertake research to study the issues with doing this type of analysis.

  - that the analysis methodology, once developed and exercized, <u>will be able to distinguish</u> which-is-which (between the non-rad-health impacts from the NPP and the impacts arising from the large external hazard itself.)

My bottom line (continued)

- **Crucially, I am convinced that the NRC needs to regulate so as to assure that the <u>entire spectrum</u> of impacts <u>from the NPP</u> would be acceptable.**

(…. which requires being able to identify them and to analyze them quantitatively !)

INEST

Institute for Nuclear Energy Science and Technology

Societal Safety Goal Workshop
March 20, 2012

Objectives of Meeting

- Discussion of the general concept – a vetting process before approaching the NRC
- Identify and discuss issues associated with the form and implementation of a quantitative societal objective
- Obtain recommendations regarding the next steps

Participants

Aldemir	Tunc	OhSU	B*
Apostolakis	George	NRC	C
Arndt	Steven	NRC	A
Bley	Dennis	ACRS	B
Brown	Gil	U. Mass, Lowell	C
Budnitz	Robert	LBNL	B
Corradini	Michael	U.Wisc, ACRS	B
Denning	Richard	OhSU	C
Dinh	Nam	INL	A
Fleming	Karl	Consultant	B
Gilles	Nan	NRC	C
Golay	Michael	MIT	C
Hudson	Daniel	NRC, JHSPS	A
Kadambi	Prasad	Consultant	C
Klein	Andrew	OrSU	A
Kress	Thomas	Ex-ACRS	B
Lambregts	Marsha	INL	
Lee	John	U. Michigan	A
Modarres	Mohammad	U. Maryland	A
Newberry	Gloria	INL, facilitator	
Sloan	Sandra	Areva	C
Smith	Curtis	INL	B
Stanculescu	Alex	INL	C
Stetkar	John	ACRS	A
Turinsky	Paul	NCState	A
Vierow	Karen	Texas A&M	B
Youngblood	Robert	INL	C

Breakout Sessions

- Group A Safety and Performance Goals and Measures
  - Candidate measures of societal impact of NPP accidents
- Group B Site Risk Issues
  - Multi-unit considerations
  - Level 3 analysis needs
- Group C Regulatory Implementation Issues
  - Quantification of societal impact of alternative energy sources
  - Potential regulatory impacts and transition issues

Workshop Conclusions

- Discussed a number of issues but there was little consensus on a path forward.
- Apostolakis said wait for NUREG-2150.
- Concern expressed that there was a need for a smooth transition – establishing a new safety goal might be too radical a change.

Alternative Safety Goals and Risk Measures

R. S. Denning
December 1, 2015

What's Wrong with What We Have?

- The latent cancer fatality QHO is considered a surrogate for societal risk but it is not.
  - Calculated as individual risk.
  - No recognition of the true nature of societal risk.
- There is a distorted view of human health risks from nuclear power plant accidents.
  - NUREG-1150 (although incomplete with regard to external event and shutdown risks) indicated that the QHOs could be met with large margin.
  - SOARCA indicated that NUREG-1150 over-estimated risk.
  - Fukushima provides further evidence.

Actual Magnitude of Radiological Human Health Risks (Early Fatalities)

- SOARCA analyses indicate no early fatalities over the spectrum of accidents.
- Since WASH-740 we have propagated the belief that a severe accident at an NPP could lead to offsite early fatalities. We were wrong.
- Even Chernobyl had no offsite early fatalities (firemen on the roof exposed to direct shine from the exposed core).
- LERF, which is oriented toward prevention of large exposures to unevacuated population, has very low probability but also very low potential for early fatalities.

Actual Magnitude of Radiological Human Health Risks (Latent Fatalities)

- No member of the public received a dose (or is expected to receive a dose) that would significantly increase their risk of incurring cancer.
- Even at Chernobyl the only epidemiologically significant impact on cancer fatalities was thyroid cancers in juveniles.
  - They were avoidable, if the Soviet Union had informed the public.
- At low doses LNT becomes a major question.
- LCF risk is a small element of societal risk (and is unobservable in the population)

Actual Magnitude of Societal Risk

- Past PRAs have under-estimated the magnitude of societal risk.
  - Apparently through the under-estimation of decontamination costs.
- Societal risk is the principal risk of severe nuclear power plant accidents (perhaps existential risk).
  - But at this point is given little direct consideration in regulation.
  - Europeans are providing regulatory requirements to strictly limit release of radioactive material in severe accidents. The U.S. is not.
- Nevertheless, the societal risk of nuclear power plant accidents is manageable and small relative to other accepted societal risks.

Candidate Measures of Societal Impact

- Do we need to measure human health impacts in natural units such as reduction in life expectancy or should all measures be monetized (or treated as utiles)?
- Is it acceptable to time average risks or do large infrequent events need to be specially weighted (risk aversion factor)?
- Do we need to explicitly recognize that large events have a disruptive impact on a nation's economy (e.g. might we limit the frequency of events that have greater than a 1% impact on the GNP)?
- How complex should the economic analysis be of lost goods or land productivity?
- Is the cost of power replacement a legitimate NRC concern to be included in the societal impact?

Candidate Quantitative Societal Objective

- The safety goals are fine. We need a QSO.
- An objective consistent with existing QHOs would be that the monetized societal risk of nuclear power plant accidents should be insignificant relative to other societal risks (e.g. less than 0.1%).
- An appropriate surrogate could be large release frequency (LRF).
  - A replacement for the LERF surrogate.
  - Could be defined as a fraction of core inventory (such as 0.1% of cesium inventory)

Level 3 Analysis Needs

- Is it necessary to perform site specific Level 3 PRAs for every site (or plant)?
- If site specific results are not required, is it necessary to redo existing Level 3 PRAs for a variety of sites or can existing PRAs be augmented?
- How can SOARCA Level 3 results be extended and used to support the development or implementation of an QSO?
- Should a primary objective of the NRC's Level 3 PRA (in progress) be to provide a basis for the development of a QSO?
- Beyond measuring land contamination and LCFs, what other offsite consequence measures should be included in assessing the magnitude of societal impact?

Regulatory Implementation

- Any major new requirement for the existing nuclear power plants can have negative societal implications that are substantially worse than the societal impact of an accident.
  - Merchant plants are already under serious economic stress.
  - Shutdown of these plants would have major impact on ability to meet greenhouse gas objectives.
- The QSO should be a future goal impacting the licensing of all future plants.
  - But could be used to risk inform regulatory decisions.
- A rational energy policy must include a significant contribution of new nuclear power plants (an order of magnitude larger than existing nuclear power plant energy generation).

Fixing the NRC's Broken Framework for Reducing Severe Accident Risk

Edwin Lyman
Senior Scientist, Global Security Program
Union of Concerned Scientists

Presentation to the ACRS Subcommittee on Reliability and Probabilistic Risk Assessment
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NTTF Recommendation 1

- UCS continues to believe in the necessity of a comprehensive overhaul of the flawed regulatory patchwork, as highlighted in NTTF Recommendation 1, that would establish a "logical, systematic, and coherent regulatory framework for adequate protection that appropriately balances defense-in-depth and risk considerations."
- Revised risk and regulatory guidance
  - PRA results should only be used only where technically justifiable and with appropriate consideration of uncertainty
  - Given uncertainties, severe accidents should be regulated more tightly – e.g. at the 95th percentile, not the mean
  - Credit for defense-in-depth should be given more weight and formalized
  - Safety goals based on collective (or societal) consequence metrics should be adopted
  - Site-specific geographic and demographic factors should be taken into account in determining new requirements
- New IPE/IPEEE program
  - Consistent methodology across the fleet
  - New SAMA analyses using revised guidance
  - "Stress tests" to identify cliff-edges and other vulnerabilities

The results of a flawed framework

- UCS strongly disagrees with a number of recent staff positions and/or Commission decisions that rejected new requirements to address mitigation of severe accident/sabotage risks by reducing the magnitude of large, **late** radiological releases
  - Expedited transfer of spent fuel to dry casks
  - Filtered vents/CPRR rulemaking
  - Containment protection for PWRs and Mark III BWRs (hydrogen control)
  - Regulatory treatment of SAMGs

The flaw in common

- These analyses had one aspect in common: each proposed action was deemed not to be a substantial safety enhancement and thus did not meet the requirements of the Backfit Rule:
  - "a substantial increase in the overall protection of the public health and safety or the common defense and security to be derived from the backfit"
  - This was determined by comparing the absolute level of safety, characterized as the average risk of a latent cancer fatality to an individual within the 10-mile EPZ, to the latent cancer Quantitative Health Objective
- However, for at least three reasons, this is an improper approach
  - The safety goals were never meant as a litmus test for determining what constitutes a substantial safety enhancement
  - The backfit rule refers to "a substantial increase." Thus the relevant parameter is the magnitude of a change in risk, not the absolute risk
  - The safety goals, which are expressed in terms of individual risks, are relatively insensitive to safety enhancements that result in significant reductions in collective measures of harm and thus are not useful surrogates for societal risk goals

Safety goals are not a litmus test

- "… the safety goals are not requirements and, with the Commission's approval, safety enhancements may be implemented without strict adherence to the Commission's safety goal policy statement." – NUREG/BR-0058, p. 9
- But even if the safety goals were intended to be used as a litmus test, the staff has used them incorrectly

Safety goal screening is based on a *change* in CDF, not an absolute value of risk

- The staff claims in regulatory analyses for CPRR and other proposed requirements that it uses the guidance in NUREG/BR-0058. However, this is simply not true:
- "For the purpose of evaluating regulatory initiatives against safety goals, the magnitude of the change in CDF should be considered in concert with the determination of whether the substantial additional protection criterion of the backfit rule is met. Specifically, a single, common criterion is to be used for determining whether a regulatory initiative involving a reduction in CDF (1) meets the substantial additional protection standard identified in the backfit rule (Ref. 8) and (2) is appropriate, considering the subsidiary safety goal of 10-4 in mean CDF per reactor year." – NUREG/BR-0058, p. 13
- Compare this to the draft CPRR regulatory analysis:
  - "… because the frequency-weighted ILCF risk for (the status quo) is already below the associated QHO, the staff has concluded that … an engineered filtered containment venting system or a performance based confinement strategy … does not meet the threshold for a substantial safety enhancement."

Safety goal screening of mitigative measures

- In fact, NUREG/BR-0058 cannot be used to evaluate regulatory changes that only affect mitigation:
  - "Furthermore, note that the safety goal screening criteria described in these Guidelines do not address issues that deal only with containment performance. Consequently, issues that have no impact on core damage frequency (ΔCDF of zero) cannot be addressed with the safety goal screening criteria."
- However, the guidance in NUREG/BR-0058 can be used in such cases by defining an effective change in CDF that results in the same reduction of risk as enhanced mitigation:
- $\Delta CDF_{eff} = CDF_0 \times \Delta R/R$

Example (CPRR)

- $|\Delta CDF_{eff}| = CDF_0(ELAP) \times \Delta R/R$

$$= 3x10^{-5} \text{ x } (3.3x10^{-4} – 3.8x10^{-5}) / 3.3x10^{-4}$$

$$= 3x10^{-5} \text{x } 0.885 = 2.7x10^{-5} > 1x10^{-5}$$

where CDF_0(ELAP) is the conservative value cited in the CPRR Regulatory Analysis, and R= individual latent cancer fatality risk within 10 miles (from Table 4-23)

- According to NUREG/BR-0058, a reduction in CDF of $1x10^{-5}$ or greater passes safety goal screening if the conditional containment failure > 0.1, which is true for all scenarios evaluated in the CPRR draft regulatory basis
- Yields different conclusion than the staff approach

Safety Goals are insensitive to collective harm

- It is clear from the Safety Goal Policy Statement that the limit on individual risks within 10 miles was intended to bound societal risks
  - Original safety goal specified a 50-mile area but a smaller (10-mile) area was judged to be more conservative
    - This is true only for individual risk metrics, not for collective risk metrics (for instance, compare 50- and 100-mile results in Table 4-21 of CPRR draft regulatory analysis)
  - Limit on acceptable individual risk was judged to also provide limit on acceptable societal risk (but see comments by Commissioner Bernthal about siting a reactor in Central Park)
- Individual risk metrics do not reflect site-specific differences in collective harm: CPRR regulatory analysis of Peach Bottom and Limerick
  - "Individual latent cancer risks "are generally similar between Peach Bottom and Limerick for a given source term size, despite the fact that Limerick has a substantially higher population in the 10-mile area," because "this is a population-weighted consequence metric""

Example: risk of long-term displacement

- Average number of people displaced annually by natural disasters worldwide: 27 million (dwarfs manmade disasters)
  - Average risk ~ 4×10^{-3} per year (1.5×10^{-3} for U.S. alone)
- Associated "safety goal" would be 1.5×10^{-6} per year if only U.S. risk is considered (note this is an individual, not collective, metric)
- But compare to the annual average risk of long-term displacement within 50 miles of Limerick as the result of an unmitigated ELAP:

  $$3 \times 10^{-5} \times 0.06 = 2 \times 10^{-6}$$

  – comparable to the safety goal
- Therefore, regulatory action would be warranted if this safety goal were utilized for screening

“Substantial increase in public health and safety”

- But would this conclusion would also hold assuming the 95th percentile CDF estimate for an unmitigated ELAP, which is a factor of ten below the conservative estimate?
- This depends on how a “substantial increase” is defined; the NRC has never clearly answered this question
- According to NUREG/BR-0058
  - a decrease of CDF of 1×10^{-4} or greater is always considered a substantial increase in safety (*doesn’t even make sense today because most plants have smaller CDFs, at least for internal events)*
  - a decrease of CDF between 1×10^{-5} and 1×10^{-4} (around 10%) may be a substantial increase in safety depending on the probability of containment failure
  - Smaller decreases may be judged substantial by a management review
- A process is needed to determine when a mitigative measure would result in a substantial increase in safety
- Typical consequence reductions associated with mitigative measures like filtering (factor of 10 or more) decrease risk far more than 10%

Conclusions

- As part of a comprehensive revision of its regulatory framework, the NRC should incorporate a wider range of severe accident consequence metrics, including collective or societal metrics, into its regulatory decisionmaking process
- The process should be able to recognize and give proper weight to safety enhancements to accident mitigation, independent of any enhancements in prevention