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Fukushima Subcommittee

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12 proceeding of the United States Nuclear Regulatory
13 Commission Advisory Committee on Reactor Safeguards,
14 as reported herein, is a record of the discussions
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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

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FUKUSHIMA SUBCOMMITTEE

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WEDNESDAY,

NOVEMBER 30, 2016

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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 8:30 a.m., Joy Rempe, Chairman, presiding.

COMMITTEE MEMBERS:

JOY REMPE, Chairman

RONALD G. BALLINGER, Member

DENNIS C. BLEY, Member

CHARLES H. BROWN, JR., Member

MARGARET CHU, Member

MICHAEL L. CORRADINI, Member

WALTER L. KIRCHNER, Member

JOSE MARCH-LEUBA, Member

DANA A. POWERS, Member

HAROLD B. RAY , Member

PETER RICCARDELLA, Member

GORDON R. SKILLMAN, Member

JOHN W. STETKAR, Member

MATTHEW W. SUNSERI, Member

DESIGNATED FEDERAL OFFICIAL:

CHRISTIANA LUI

ALSO PRESENT:

ERIC BOWMAN, NRR

KEITH COMPTON, RES

KEVIN CROWLEY, NAS

HOSSEIN ESMAILI, RES

STEVE JONES, NRR

RICHARD LEE, RES

BILL RECKLEY, NRR

JOE RIVERS, NSIR

RICHARD F. SCHOFER, NRR

JOE SHEPHERD, NAS

ANDREA D. VEIL, Executive Director, ACRS

* Present via telephone

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P R O C E E D I N G S

(8:31 a.m.)

CHAIR REMPE: Okay. This meeting will now come to order. It's the meeting of the Advisory Committee on Reactor Safeguards Subcommittee on Fukushima. I'm Joy Rempe. I'm the chairman of this subcommittee meeting.

Members in attendance at this meeting include Pete Riccardella, Charlie Brown, Walt Kirchner, Jose March-Leuba, John Stetkar, Dennis Bley, Mike Corradini, Dana Powers, Dick Skillman, Harold Ray, Margaret Chu, Matt Sunseri and Ron Ballinger. Christiana Lui of the ACRS staff is the designated federal official for this meeting.

The purpose of the meeting is for the subcommittee to receive information on the National Academy of Sciences Phase 2 study on lessons learned from the Fukushima nuclear accident for improving safety and security of US nuclear power plants.

The subcommittee will hear presentations by and hold discussions with the Academy's Phase 2

study chair and the NRC staff.

The subcommittee intends to gather information, analyze relevant issues and facts and formulate proposed positions and actions as appropriate for deliberation by the full committee.

ACRS member Mike Corradini was a member of the National Academy of Sciences Fukushima's Lessons Learned Study Panel and he will limit his participation during today's meeting, right, Mike?

(Laughter.)

CHAIR REMPE: This meeting is open to the public and is being conducted in accordance with provisions of the Federal Committees Act.

Rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on November 18th, 2016.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register Notice.

Therefore, we request that all speakers first identify themselves, speak with sufficient clarity and volume so that they may be readily heard, and use the microphones located in the meeting room

when addressing the subcommittee.

Also when speaking into the microphone, please make sure -B and this is for you, Joe, and actually the members, too, because we forget -B that the green light indicator is on. And we ask at this time, that you silence any phones or other electronic devices in the room.

Prior to today's meeting, we didn't receive any written comments or requests for time to make oral statement from members of the public regarding today's meeting.

Although we have a bridge line open, to preclude interruption of the meeting the phone bridge will be placed in the "listen only" mode during the presentations and committee discussions. And we'll open the bridge line at the designated time and during the meeting for public comments.

I will now proceed with the meeting and I'd like to invite Professor Joe Shepherd to begin his presentation.

MR. SHEPHERD: Thank you, Joy.

Good morning, ladies and gentlemen. I'm Joe Shepherd. I was the chair of this committee, the National Academy Committee, that worked on the Phase 2

of this report.

I'm going to be reporting today about what we did between July and -B 2014 and May of 2016, and that resulted in this report.

As you can see, there was a first phase which we carried out and completed in July 2014. I was a member of that committee and participated in that as well. Here, we're going to be focusing on just this second report.

Now, this was a committee that was composed of a number of individuals. You can see them listed here. Myself, Bob Bari, Jan Beyea, Mike Corradini, as Joy already mentioned, Vijay Dhir, Mike Golay, Barbara Hamrick, Paul Locke, Tom Moser, Art Motta, John Orcutt, Emilie Roth, Liz Ten Eyck, Frank Von Hippel and Loring Wyllie.

And I'd like last, but certainly not least, to acknowledge Kevin Crowley who is here today, who was the study director. And anyone who's been involved with one of these National Academy studies, knows its success really hinges on having an experienced and superb director, as Kevin was.

So, this was the work of the Committee as individuals, and then collectively. And these

National Academy committees, many of you have been involved in them, will know involves developing a consensus which can be sometimes an arduous task, but it is a consensus.

And what I am going to be doing here today is representing that consensus of the Committee. And that's what I'm going to really be speaking to.

So, I B first of all, let's just talk about what it is that we did. The task statement, this is somewhat abbreviated, but gives the essence of it for this phase, was to first of all look at the lessons learned from the accident itself for improving the safety of spent fuel storage.

And so, that involved considering, in detail, the events around the spent fuel that was stored at Fukushima Daiichi particularly during the period and the immediate aftermath of March 11th.

The second issue that we were tasked with examining is security-related lessons, that is, the physical security of the plant and the spent fuel pool, and particularly the lessons learned from the Fukushima Daiichi accident that could be applied to improving the systems, operations and regulations here in the United states.

MEMBER POWERS: What particularly motivated an interest in security here? I mean, after all, you've kind of destroyed all of the surrounding countryside with a tsunami and it's a total mess.

What motivated somebody to think that security was the biggest B

MR. SHEPHERD: Well B

MEMBER POWERS: -- focus to B or the second focus here?

MR. SHEPHERD: Well, certainly you pointed out the major effect of the accident and we considered that at length in Phase 1.

But one of our tasks that we were given as part of the charge from Congress, was to reexamine the 2006 report that was done. And B I don't know. You were probably here at that time. I don't know if you reviewed that or not.

MEMBER POWERS: Probably.

(Laughter.)

MR. SHEPHERD: Yeah. I'm not going to speculate as to your longevity, but B so, yeah, that was B in fact, one of the motivations was looking at what had been recommended in 2006. And that actually goes on to the third point here, reevaluating the

findings and the recommendations from previous National Academy reports on spent fuel storage safety, because in 2006, it was primarily concerned with spent fuel, but there were security concerns that were brought up by Congress.

You've not only destroyed the countryside, but you also had disabled all of the features that allow you to control access to the plant and B

MEMBER POWERS: Well, not B not the one provided by a substantial radiation dose, presumably.

MR. SHEPHERD: Well, we can argue about the protective nature of it, but, you know, there may be some folks who are willing to take that risk. So, that was the motivation for looking at security, Dana.

CHAIR REMPE: Joe, when I look at your report in the findings and recommendations and I think about what I see here at the NRC, it seems like your committee is not concerned with B or did not consider some of the policy decisions that the NRC has to consider, some of the B which includes the Commission's emphasis on risk importance in forming our regulations.

And you also have B don't consider some of the laws that have been enacted by the Supreme Court,

in some of your recommendations.

And is that like a gap, perhaps, in the way Congress has directed B or the way the Academy takes on their chores that maybe you're giving an incomplete picture, in your opinion?

MR. SHEPHERD: Well, I think that you raise a very good point, which I'd like to explore a little bit.

And one of the things about these National Academy committees and the way they're set up and the real value of them, is B is they are committees which are not designed to provide guidance on B on policy or make policy.

They're really a group of subject matter experts who are there to examine the technical basis of the decision-making and the tools that are used in the decision-making and the technical aspects. In this case, the events that took place at Fukushima.

Now, we did think a lot about risk. In fact, we have fairly substantial discussions about risk in connection with security. And also, we considered at length what the NRC staff had done with the spent fuel safety study at quite some length in Chapter 7. And so, you know, there B we did consider

elements of that.

We didn't try to make law or ignore it, but we really tried to focus on the things that we were really best equipped to do, which is commenting on the technical basis using the expertise of the members of the Committee.

How's that?

CHAIR REMPE: I think I'm going to be having more questions along that line as we go through this, but I just B

MR. SHEPHERD: Absolutely. And I B

CHAIR REMPE: Clearly, you would have different results or recommendations if you had some of the constraints the regulator has?

MR. SHEPHERD: Well, we didn't actually make suggestions, I believe, that are contrary to any of the regulations.

I mean B but, in fact, I think it's important to recognize they're two really separate types of activities.

Regulatory work by the NRC is, of course, a necessary and essential part of their function and they have a regulatory perspective.

The Committee members, although some have

a background in working in the NRC, we have several members that have been involved extensively with it, their goal is really to provide a technical perspective on this B

CHAIR REMPE: Uh-huh.

MR. SHEPHERD: -- rather than a regulatory one.

CHAIR REMPE: Okay.

MR. SHEPHERD: And you're absolutely right. One has to take these results and say, now, how can we use them?

And like all committees and consultants, you know, you can say, "Well, you guys didn't pay attention to any of the things we care about," but, in fact, the Committee is saying, "We think you ought to think about some of these things."

CHAIR REMPE: Okay.

MR. SHEPHERD: Okay. So, that said, the final thing that we did was reevaluate the findings and recommendations.

It says, "previous NAS reports." That's because there were two versions of the 2006 report. There was a 2004 version that was classified and a 2006 unclassified version, but essentially the content

of those is the same with just a few exceptions. And those B that report focused exclusively on the spent fuel storage safety and security.

So, if there's something that distinguishes what we did in this report from the previous report, that's the focus on the spent fuel in addition to security.

So, the report has 14 findings and recommendations. This is the bureaucratic structure of these reports is to make a technical analysis. Based on that technical analysis, then you arrive at some findings. And then those findings are the basis for making some recommendations.

We didn't prioritize those recommendations, but we can share we will later in the discussion talk about what some of the potential gains are with some of those.

Okay. All right. Let's get into the meat of it then if there's no further questions about that introductory material.

All right. So, the first thing we did was we looked at what happened at Fukushima Daiichi in regard to the spent fuel storage facilities.

So, the most important thing, which we all

recognize, I imagine that many of us here have paid very careful attention to what happened during that time, is that the spent fuel storage facilities maintained their containment functions during and after the earthquake and the tsunami, but there were some things that the Committee noted that were quite troubling.

For example, we had explosions that took place in Units 1, 3 and 4, which very substantially damaged the reactor buildings.

These being the BWR units, they have B the fuel storage is at the top of the reactor building. And the upper part of that building, which is basically the containment over the pool, that was destroyed in three cases.

So, that's B in addition, there was a substantial amount of debris that was introduced particularly in Unit 3 where the fuel handling machine and quite a bit of concrete and steel went into the pool. And that, of course, is something that is troubling.

But, fortunately, it does not appear that any of the fuel was damaged to the extent that they had a noticeable release of fission products or

transuranics.

The thing that did concern the Committee was the lack of reliable realtime information about the pools.

The loss of power, the inaccessibility of those areas created substantial difficulties in responding to the accident and it led to a lot of anxiety because there was a lack of knowledge.

And in the absence of knowledge, there is frequently speculation. And speculation often goes to places that are kind of dark and creates a lot of anxiety.

Despite all these things, though, the plant personnel were able to improvise and provide the necessary cooling to avoid any uncovering of the fuel and the potential radiological consequences.

We did note, though, that there was a very serious situation in the Unit 4 pool which had to do with that reactor being in outage and having a full offload. And I'm going to talk about that in a little bit more detail.

CHAIR REMPE: Before you leave B go ahead.

MEMBER SKILLMAN: Joe, before you leave that slide, please, the robustness of the mechanical

structure of the fuel in Unit 3 resisting, if you will, concrete and structural steel falling on top of the fuel, what credit is given to that notion?

I B it just seems to me that there's been this B this momentum of "ain't it awful these buildings can collapse, we can have all kinds of problems, the fuel's in there, hurry up, hurry up, get it out," and then there is this maybe colossal piece of information that the fuel even if it's been impinged by structural material and by concrete, actually pretty much stayed intact.

It seems that that is an important finding and it doesn't get any B doesn't get any press.

MR. SHEPHERD: Well, I actually think they were just lucky, because the fuel handling machine fell in the part of the pool where they B they do the gas loading and there wasn't any fuel.

And so, the B most of the steel of the fuel handling machine went into that part of the pool. There was a lot of concrete on top of the racks and I think you have to give substantial credit to the racks, actually, rather than the fuel itself.

The fuel, of course, is quite fragile in some sense.

MEMBER SKILLMAN: But if you were to impact that directly --

(Simultaneous speaking.)

MR. SHEPHERD: And so, the baskets that you have for the BWR and the racks, have substantial strength and are probably the things that enabled it to go undamaged.

MEMBER SKILLMAN: Well, I agree with you on the racks, but I disagree with the fuel. I think the fuel, if it's intact and if it's not overheated, is quite a rigid structure. I mean, it's a strong box. And if you lined up hundreds and hundreds of strong boxes, that is a very strong structure.

MR. SHEPHERD: If you have fuel assemblies, if you have intact fuel assemblies, you know, they are within the protective structure of the racks, but the fact of the matter is at this point, now, I'm speculating because I don't have any knowledge of that and the Committee didn't examine it.

MEMBER SKILLMAN: Understand my point. I'm suggesting that the fact that there was that collapse onto that fuel in Unit 3, and that fuel did not breach and have radionuclide release, is a piece of information that seems to me needs to be heralded

and not obscured. That's an important piece of information.

MR. SHEPHERD: Well, that's certainly something that the NRC staff could do.

MEMBER POWERS: The other point all along this is we've taken, what, three sets of spent fuel pools now, put them through earthquakes that exceed the design basis and nothing.

I mean, we have B it seems to me that the first thing I see when I look at these spent fuel pools, is, damn, those are pretty good structures.

MR. SHEPHERD: They are very substantial structures, but I think there are some things to be concerned about and those are some of the things I'd like to go through here.

MEMBER STETKAR: Joe, you mentioned that you thought we were lucky and you mentioned that the fuel handling machine fell in a place that was not where fuel was.

Isn't that pretty much intentional? People park those machines away from the fuel intentionally unless they're actually moving fuel, which is only a very, very small fraction of the time and will -B exposure period from these plants.

So, the fact that it fell where there wasn't fuel just says that they were actually following their normal process, because B-

MR. SHEPHERD: Well, I don't B-

MEMBER STETKAR: -- you wouldn't expect it to fall B-

MR. SHEPHERD: I don't know B-

MEMBER STETKAR: -- where there's fuel.

MR. SHEPHERD: I don't know where it was parked.

MEMBER STETKAR: Well, it probably was parked pretty much above where it fell.

MR. SHEPHERD: I didn't think it was -B I don't know. But I'll tell you this: You had a very extreme and energetic event in Unit 3 in terms of if you just look at the destruction of that concrete structure, I mean, it totally destroyed that floor. And, also, severely damaged the floors underneath. Unfortunately, you're not able to get in there and look at it because of the contamination. And it moved around pretty good-sized pieces of concrete.

And so, I'm not sanguine about the ability of that to stay put when you have a large explosion like that.

MEMBER STETKAR: Well, move pretty good chunks of concrete laterally by large distances, or just move pretty good chunks of concrete from an upper elevation to a lower elevation?

MR. SHEPHERD: Again B-

MEMBER STETKAR: Things tend to fall down.

MR. SHEPHERD: -- the Committee did not get into the details of that.

MEMBER STETKAR: Okay.

MR. SHEPHERD: I'm just suggesting that you had B-

CHAIR REMPE: The videos are out there. You can see B but before you leave that slide, when you talk about increased public anxiety, in my opinion, which is, again, just my opinion, some statements made by a former chairman of the U.S. NRC increased public anxiety because they didn't actually qualify those statements with enough information about the assumptions made to say that the spent fuel in Unit 4 was dry and that they were making a lot of conservative assumptions based on lack of knowledge.

And so, again, when they finally found out that there's water in there, if that -B if they put enough caveats, it might have been better.

So, when I looked at your report, I'm a little confused about what your group believes was the cause of the leakage.

Was it accidental, as it's stated on page 6, that water B that the water leakage was accidental, whereas on page 72 your report states that the gates mounted to allow for such leakage?

So, do you guys think it was accidental that the gate allowed leakage into the spent fuel pool, or do you think it B

MR. SHEPHERD: So, Joy, we're getting a little bit ahead of ourselves here.

CHAIR REMPE: Yeah.

MR. SHEPHERD: And so, I'd like to back up and address your first issue about public anxiety.

CHAIR REMPE: Uh-huh.

MR. SHEPHERD: I think no matter who is in charge whether it's in the United States or another country, when you have a lack of information, that this really creates a very difficult situation for the decision-makers and the folks that are representing the situation to the public. That's all we're trying to say there.

CHAIR REMPE: Yes, but B

MR. SHEPHERD: And so, that's B

CHAIR REMPE: But maybe if those individuals in the public B

MR. SHEPHERD: That's what the Committee's point was.

CHAIR REMPE: Yeah. Well, again, you might have come up with a recommendation saying that it's very important to not increase unnecessary public anxiety by stating, "I'm making a lot of conservative assumptions."

We had the same thing after TMI with the hydrogen bubble, right? And so B

MR. SHEPHERD: And, again, that was an example where there was a lack of information and a lot of speculation. And so B

CHAIR REMPE: And they need to B

MR. SHEPHERD: -- you know, that's really B

CHAIR REMPE: -- explain that we don't know sometimes and there's speculation instead of making bold statements, "We believe the spent fuel pool is dry," in this case.

And so, again, yeah, it would have been good to have instrumentation B

MR. SHEPHERD: I don't think we're in disagreement, Joy.

CHAIR REMPE: Yeah. The public anxiety sometimes is caused by the officials making these statements.

MR. SHEPHERD: I understand.

CHAIR REMPE: Yeah. So, that's that point.

MR. SHEPHERD: Now, we got ahead of ourselves a little bit because you mentioned spent fuel pool 4. And so, if you'll allow me, I'd just like to go through some more steps in my presentation and come back to that.

CHAIR REMPE: Okay, but we B at some point, again, because you have "leakage of water into the Unit 4 pool" right there on that slide, I'd like to know what your group believes, because I'm not sure, because I see two different viewpoints.

Was it B is the gate supposed to be mounted to allow that leakage, in your group's opinion, or was it accidental?

MR. SHEPHERD: Okay. Let's B let's go through this and then come back to that B

CHAIR REMPE: Okay. Sure.

MR. SHEPHERD: -- because there's a figure I'd like to use to talk about this.

Is that okay?

CHAIR REMPE: Okay. You bet.

MR. SHEPHERD: All right. So, I don't need to go through this. These are the locations where the fuel was stored. Everyone, I think, is familiar with this.

This is the Unit 4 that we're now going to speak about. And so, this is a view into Unit 4 that was taken during a helicopter overflight to try to determine if there was water in the pool.

And so, one of the things that was concerning, of course, was the extensive destruction that you see here and then the fact that there was a fairly substantial amount of what appeared to be steam coming out of Unit 4, which meant the core was completely offloaded into the pool.

The pool was 98 percent full and was about 2.6 megawatts of decay heat and it was without any B and a complete loss of cooling in that pool.

And if there had just been that pool alone and no other water source, it would boil off about seven-tenths of a meter or about 80 tons a day. It

would have boiled down to the midpoint of the fuel in about 14 days. They were able to reestablish some cooling by using concrete pump trucks on about day 11 of this.

Now, what happened? This is about the gates. I'm going to jump ahead here so we can use this figure to talk about the gates.

So, what we can see here are some figures that illustrate what happened with the gates, and what TEPCO believes happens, and what the Committee believes happens, based on analysis of the water levels and energy and mass balance in the pool.

The system was in outage. They had removed all of the core that's in the pool. They had removed the steam separator and the annulus around the core and it was placed over here in the dryer-separator pit and they had filled the pit with water. The pit is on the left-hand side. Ordinarily, that pit is dry.

Now, as the water boiled off, as I said, you're boiling off about 80 tons a day, there's a complete loss of cooling. We had no cooling operational whatsoever. And as that water level lowered, then the gates B and I don't know whether

this B we do not know if this was an intentional design or not.

We have no indication that this was an intentional design, but the way these gates are constructed, these gates use an elastomer seal. And it's the force of the water in the pool that pushes that seal up against the wall, there's two gates, and that's what seals that. It's just by the force of the water.

Now, if the water level drops on one side and there's water on the other side, which is a situation you only have during this type of maintenance procedure, then you can B the design of the gates is such, and we don't know if this is intentional or not, but because the gate is just hung in place, it can ride up on what its hung on B and let's see if we can see a picture of how it's hung.

CHAIR REMPE: Actually, you keep saying you don't know if this is intentional B sorry. You keep saying you don't know if it's intentional, but I'm looking at page 72 of your report B and that's not the PDF, it's like PDF 89 out of 239 -- but on page 72 when the water level on the well side is higher than in the pool, the gate is mounted such that the force

due to the difference in water level can displace the gate sufficiently that the seal is ineffective and water will flow from the well into the pool.

And I actually discussed this with some BWR owner group folks and they said, "Absolutely, that thing is supposed to leak. That's the way it's designed."

And so, again, on page 6 of your report B

MR. SHEPHERD: That is not B that was not information that we had.

CHAIR REMPE: It's in your report.

MR. SHEPHERD: Well, no. What's in our report is that this is the way that the gate is mounted and this is what will happen.

We didn't say that it was designed this way, it's just that's the way it's put in there.

CHAIR REMPE: But that's B

MR. SHEPHERD: Whether that was intentional or not B whether they had the foresight to say, "There's going to be a situation where we have loss of pool cooling, we're going to have water on the other side and we want to make this happen," I don't know if that's B

CHAIR REMPE: That's what I've B

MR. SHEPHERD: -- the case or not.

CHAIR REMPE: -- heard that that is the case. And I believe that's what B

MR. SHEPHERD: Well, we never B

CHAIR REMPE: -- other members here are saying.

MR. SHEPHERD: We didn't have any information to that effect.

CHAIR REMPE: So, then, if you can follow up and verify that, do you think maybe the statement on page 6 of your report that says it was accidental leakage should change? Because this is B I mean, basically, if you realize that's the way they're intended to operate, then this curve that you skipped over where you have the black line where B

MR. SHEPHERD: Well, I'll tell you what. It would be very interesting if we could B we didn't get that data during our time that the Committee was active. It would be very interesting if someone would come forward and say, "Oh, yes, we designed them to work this way all the time," because I B we've never heard that.

CHAIR REMPE: Well, I B

MEMBER KIRCHNER: Did you not get the BWR

people B yes, I've got it. Didn't you get either representatives of GE or TEPCO or someone to present to your B

MR. SHEPHERD: We had TEPCO present B

MEMBER KIRCHNER: You could have asked this question.

MR. SHEPHERD: We had B we had liaison with TEPCO and we had extensive discussions with them.

CHAIR REMPE: And, in fact, TEPCO was the B

MR. SHEPHERD: Kevin can comment here on who presented.

MR. CROWLEY: Do I need to go to a mic?

CHAIR REMPE: Yes. And you have to identify yourself, too.

MEMBER BLEY: Say who you are and where you're from.

CHAIR REMPE: Even though we know you.

MR. CROWLEY: I'm Kevin Crowley. I'm from the National Academy of Sciences and I was the study director for this project.

We not only got presentations from TEPCO, but when the report went to review, we cut out a lot of the factual material and sent it back to TEPCO and

asked them to fact check it.

And one of the reviewers for our report was a GE person, and we had had discussions with that person during the study.

So, I think it's pretty fair to say that we made a B the Committee made a very good faith effort to make sure that it had the most current information.

CHAIR REMPE: But again, I'm reading the report statement. It says, "Water will flow from the well into the pool," and it has a citation from TEPCO.

If I were a TEPCO person, and I'm guessing even the BWR owner's group people, would believe the statement on 72 of your report and say that's fine.

MR. CROWLEY: You know, as Joe said, that statement on page 72 is a statement of fact. And what you're doing is you're taking an additional step and you're imputing an intention.

I could imagine that if you would design B here, I'm just speculating. I would imagine if you're designing those gates, having a gate that would seal up against the wall so you don't leak water out of the pool, is a very logical thing to do.

As Joe said, whether or not they went

through the mental exercise of trying to game out a scenario where you might have a higher water level in the reactor well than you do in the pool, which would cause reverse leakage, we had no information to suggest that that was the case.

And, again, you know, in our discussions with TEPCO in asking them to fact check the statements in the report, they didn't flag those.

CHAIR REMPE: Yeah. Well, I think it B again, so I guess what the answer to my earlier question is, you believe it was an accidental leakage, as indicated on page 6 of your report.

MR. SHEPHERD: We have no indication that that was a design in the feature. So, it has a very important consequence, though.

We believe the Committee analyzed this in some detail. A number of groups have analyzed the mass and energy balance in the spent fuel pool.

What's shown here in this graph is a plot of three lines. The blue line is a best estimate water level in the pool accounting for both the evaporation due to the decay heat and the spent fuel, and the leakage, setting aside intent, through B back through the gates from the dryer-separator pit into

the B into the pool.

That's the blue line. So, there's some measurements on there and this is based on the information that B best information that we have from TEPCO and the control volume engineering model that takes account of heat loss, evaporation and fluid flow.

The orange line that has fewer zigzags in it -- the zigzags correspond to water addition by TEPCO using primarily the concrete pump method.

The orange line is what we estimate as the water level in the dryer-separator pit and reactor well area. And that shows that level falling commensurate with the decrease in the level of the pool itself until about April the 20th when they began to seriously add water and monitor the level in the pool and it appears that the gates were resealed.

Now, what I'd really like to draw your attention to is the black line here which shows what would have been the consequence had that pit not been flooded.

And that shows that early in April, you would have reached the top of the active pool and fuel even with some of B taking credit for some of the

water additions due to the very large decay heat from that full core offload.

So, the Committee believes that this was not something that was necessarily anticipated by the designers or the operators. And it certainly is something that we believe is, you know, cause for concern.

It's a very particular sort of situation. You're in outage, you have a certain type of gates, it's not clear whether the gates in other pools would have behaved in this fashion or not.

The gate design that's used in this plant is somewhat different, I understand, than the gate design that's used in the US plants.

And in any case, though, this was something where this particular feature played a very important role in maintaining the water level above the top of fuel not only to provide cooling, but also to provide the necessary shielding.

CHAIR REMPE: Could you elaborate on why you think the gate at this plant is different? What is the difference between the way it's designed versus the US B

MR. SHEPHERD: So, our understanding is

that many of the gates in BWR plants in the United States, use a pneumatic seal that has to be inflated.

I see Dana Powers nodding his head. So, it B in fact, if you B if you lose power to the compressor that powers the seals, I think the seals will B

MEMBER POWERS: So, you've called attention to your black curve there. That's the unmitigated B just the boil-off and it's 20 days to get to top of active fuel. Isn't that an extraordinarily comforting thing?

Since most of our accident management features are focused heavily on 24 hours, and you're telling me I have 20 days to get around to doing something B

MR. SHEPHERD: You're looking at B

MEMBER POWERS: Joe, you have to be on the mic, because we pick you up. Use the mouse.

MR. SHEPHERD: I apologize. I'm doing what all professors do and going to the B what smacks of a blackboard.

(Laughter.)

MR. SHEPHERD: Well, I mean, that point right there would be the unmitigated result. And

that's about B

MEMBER POWERS: If it was even 10 days, I don't think it changes if it's 10 days. That says to me, that this is a pretty low priority in my accident response activity. I've got lots of time, lots of time, days to get around to dealing with this pool situation, whereas I'm a little more time-limited on the reactor core.

And most of our emergency responses are geared to having equipment brought to the site within 24 hours.

MR. SHEPHERD: Well, Dana, I would agree with you if we were just dealing with this event in isolation. But, you know, clearly that was not the case here, and that's one of the issues.

They were not able to focus on this for some time and they had multiple things going on at this site. So, you know, this is a particular concern when you have a highly-contaminated area where it's inaccessible and you don't have any measurements and you have difficulty getting water in.

MEMBER POWERS: Well, if you had measurements, you'd still have difficulty getting water in, but I'm thinking in terms of our response to

the Fukushima event.

You know, we're very much geared up now to having capability to provide water from extra plant equipment within 24 hours. And when that B let me ask YOU another question.

Did you have available to you dose information should you uncover the spent fuel?

MR. SHEPHERD: Yes, and we discussed that. We B dose calculations were given in several reports. They were given in the Sandia report and an EPRI report. I think ORNL also did some dose calculations and we have a table here on page 51 of the report which talks about what the doses would be with various levels of water.

And so, you B

MEMBER POWERS: So, you would have a fairly unequivocal signal when you uncover?

MR. SHEPHERD: You could have if you were, you know, had the capability to be measuring the dose close to that area.

I mean, that area was pretty hot. It was pretty confusing at that time where all that B all those gammas were coming from. So B

MEMBER POWERS: 10 or 11 days afterwards

it's not so confusing, and it wouldn't be from this. You would have B

MR. SHEPHERD: Certainly at Fukushima it was confusing.

I guess I would like to back up a little bit and speak to your comment about the things that have been done today.

The Committee did comment on the value of the FLEX system, the value of B5B. And, you know, many B and of course we're doing this study and we're now, you know, five years out almost from this event. Almost it will be, I guess, six next year, right? Can I do that subtraction correctly? And it also takes some time for these committees to do their process.

So, while we were doing this, of course it's not a static situation and the industry and the Nuclear Regulatory Commission did many things. And we did take note of those things and gave credit for them. We think that these are very valuable things.

The one thing that did concern the Committee about the approach to mitigation in the pools is the approach when you have a complete loss of coolant, is to use sprays. It's not effective to try

to reflood it if you've got a large, large hole in the pool. This is one of the conclusions that came out of the spent fuel safety study.

And in order to use sprays, you've got to be able to get up there on the deck and you've got to be able to get your lines up there and you've got to put your nozzles in place. And these are things that are portable and have to be put in there by personnel or put in there remotely.

And the Committee suggested that it would be good to have pre-positioned nozzles and lines that could be used so you didn't have to get up there on the deck if you did have to spray. And that's our comment about that.

MEMBER POWERS: Yeah. That always causes confusion because if I bust a nuclear power plant with an earthquake or something, your pre-positioned lines are toast.

MR. SHEPHERD: Absolutely. And that was a problem. They tried to use some of the existing lines at Fukushima, and in some cases they were damaged.

For example, that was the case in Unit 4. They wanted to use a line that was going into the pool and it was pretty badly damaged.

MEMBER POWERS: So, having four pre-positioned lines that break is no better than having two pre-positioned lines. I mean, pre-positioned stuff in very severe accidents just don't do you any good.

MR. SHEPHERD: Well, that's an interesting conundrum to get into then.

How are you going to deal with that, Dana? I mean, you have to have something there.

MEMBER KIRCHNER: You use your fire B you use your fire suppression equipment.

MR. SHEPHERD: Well, I think that the thing the Committee was --

MEMBER KIRCHNER: Because they're flexible --

MR. SHEPHERD: -- concerned about in this particular case was the --

MEMBER KIRCHNER: -- and pre-positioned.

MR. SHEPHERD: -- inaccessibility of a lot of these areas. If you have a solution for an area that's inaccessible and that solution doesn't involve fixed, rigid equipment, then, you know, that's certainly something that's valuable.

And I think what we're suggesting here is

that the inaccessibility of the areas is one of the lessons learned from Fukushima.

MEMBER POWERS: And one of the requirements for having multiple accesses to the sites in this country. Isolating criteria require multiple access.

MR. SHEPHERD: Okay. So, we spent quite a bit of time on this. We actually did more in the Committee in this. And so, I'm going to move forward with this. This is some of the debris on the spent fuel and the racks that we were discussing earlier.

CHAIR REMPE: Before you leave 3, because that's a different situation, obviously, because it didn't have the well flooded and things like that like they do during defueling like they were doing with Unit 4, the report makes inferences about the gate at Unit 3.

And did the Committee discuss if there was any damage in the ability of the gate at unit 3? I mean, after they realized and they added more water to the Unit 3 spent fuel pool, it held, right?

MR. SHEPHERD; We don't know exactly the situation there. It's B Unit 3 is difficult to learn much about because of the contamination necessary to

do remote work.

The Committee really limited itself to the factual observation that the inner gate was completely displaced in this case, which is something that was only discovered after they were able to remove enough debris to look at it and it's something that we don't know why that occurred or what the effect of that is, how much leakage there is.

There's a backstop there. There's a pretty large piece of concrete there. And of course there's the shield plug on top of the reactor well, but we actually do not have any measurements or engineering evaluation what the effect of it is, but we felt that that was something that was concerning.

CHAIR REMPE: Well, in fact, you even made inferences about that, jeepers, they've noticed a lot of problems in the US with leakage of the gates. And you reference a 1997 NUREG. But I actually went through and pulled that report, and a lot of the errors that had been observed were due to human errors in the operational report.

And the staff actually B and when they come up, we'll ask them about it, but I believe it was, you know, the Commissioners were notified at the

time back in 1997 and appropriate actions were taken in the plants, is my understanding, in response to that report.

And I didn't know how far did the Committee go and, I mean, you reference this was brought up to the attention in this NUREG B or this 1997 NUREG report, but you didn't really talk about what actions the staff did and how the US industry had addressed that report.

MR. SHEPHERD: Well, the US industry has never confronted this particular situation, Joy. And so, you know, we don't have any way to respond to that.

The Committee wanted to just draw attention to the fact that this gate was severely damaged as part of this accident. And that could have implications for accident management in the spent fuel pool. That's what our B that's what our point is.

CHAIR REMPE: So, when the staff comes up, I would like to have their response on how the staff thinks that report was addressed in 1997, but we'll wait until they come up.

MR. SHEPHERD: Yeah. Well, it will be interesting to hear that.

CHAIR REMPE: You bet.

MR. SHEPHERD: Okay. So, we've had extensive discussion about this. And the Committee felt and I can see that there's substantial contention about this, but this was the Committee's judgement that these events should serve as a wake-up call to -- illustrates the importance of having robust and redundant means to measure, maintain and, when necessary, restore pool cooling. And as we discussed earlier, you know, substantial efforts have been made in that direction.

So, we had a recommendation and we felt that there should be some improvements that go beyond the current post-Fukushima response and this is something that I'm sure we'll hear from the staff about later on. In particular, Item 5 is one that we just had exchange with -- about here with the Committee.

All right. What I'd like to do at this point in the interest of time, is to move on to the next topic that we looked at, and that was the lessons learned for security.

And as Dana properly noted earlier, you know, this is something that you might consider minor

in terms of the overall effect of the Fukushima accident, but there is a question of what happened to the security infrastructure, the systems and the staffing? And we noted a number of facts about what occurred there as far as we could tell.

We were not able to get a lot of detail from our colleagues in Japan although we had very good relationships with them and we had a number of briefings and looked at a lot of material, but it was clear from the state of the plant for some time following the earthquakes and tsunamis, that there were opportunities for folks to intrude.

Now, would that necessarily happen? No, but the potential is there. And it B- the Committee felt it increases susceptibility of critical plant systems to malevolent acts if you had lost your security infrastructure.

So, the recommendation was that B- really to strengthen the ability to both make sure that the infrastructure stays in place, and also to provide -- an analogy to the provisions for accident mitigation in the FLEX system -- to also provide diverse and flexible approaches for coping with and reconstituting the plant security infrastructure. So, that's really

what the essence of this recommendation is.

CHAIR REMPE: So, when I looked at this in the report, I understand it's difficult to put a frequency on security events. But when you have "and severe accidents," there are -B I mean, did your group talk about, well, how -B how far down in frequency do you have to go? I mean, is there a cutoff frequency that you guys B- I mean B-

MR. SHEPHERD: So, this is B-

CHAIR REMPE: -- sometimes statements in your report about you should continue to make these plants safer, did you guys ever talk about, well, at some point there should be a cutoff?

MR. SHEPHERD: Well, actually, we did. And so, I think one of the important things here is that we were concerned about risk very substantially. We don't have a way to evaluate that risk, because, in fact, the security posture is not thought of in a risk-informed context where we have actual probabilities on these.

MEMBER STETKAR: That's not quite true. Risk assessments have looked at vulnerabilities of security systems in the past. They're just not made very public to people.

MR. SHEPHERD: Well, they certainly weren't made public to us. And our impression was there was a very extensive reliance on the design basis threat as a way of developing that.

MEMBER CORRADINI: John, just for effect, you're talking the US?

MEMBER STETKAR: I'm not aware of the US.

MEMBER CORRADINI: Okay.

MEMBER STETKAR: But just to make general statements that they're not included is not B

MR. SHEPHERD: Well, here specifically we're talking B

MEMBER STETKAR: And I don't know whether they have been in the US or not, because I haven't been involved in any studies in the US kind of within the last 20 years, but I know of studies internationally that have looked at risk implications from events like seismic events and fires and floods and those types of things.

MR. SHEPHERD: Well, there's been a very substantial amount of work on risk assessment in many areas. But in the specific area of examining the security issue, that is what we were commenting on.

MEMBER STETKAR: Yeah, I know. And what

I'm saying is, risk assessments have not looked at quantifying the threat from, let's call it, sunny-day terrorist attacks.

Risk assessments have looked at the vulnerabilities of security systems, power supplies, infrastructure to damage that occurs at a plant due to events such as seismic events, large floods, internal fires in the plant and things like that.

I know this for a fact, because I've been involved in a couple of them. And I know other people who have done it that B but they just don't share that part of the risk assessment, as you might well understand why.

MR. SHEPHERD: Well B

MEMBER STETKAR: So, you're correct in the sense that risk assessments have not tried to quantify, as I said, sunny-day terrorist attacks, because quantifying the frequency of that particular threat is difficult to impossible depending on who you speak with.

But looking at onsite vulnerabilities of security systems and their behavior in the context of these other types of threats whether they arise from B when I say "threats," I mean hazards B inside the

plant or from external sources, that has been done. And I don't know in the US.

MEMBER BLEY: I certainly know what John is saying is true. On the other hand, what their committee had done, as I understand it, was look to see what's typically done here in response to looking at security within plants, looking at how that's regulated and saying that it's not typically part of the normal regulating process and I think they recommended that it should be.

MEMBER STETKAR: And that's B

MEMBER BLEY: Did I get that right, Joe?

MR. SHEPHERD: So, are we both right? I don't understand "sunny-day-terrorist" either. It's a pretty gray day today and we B you know, I hope we don't have any terrorism, but it could happen.

MEMBER STETKAR: It's jargon people talk about sunny-day failures as random events that are not correlated to other things.

MR. SHEPHERD: It's always sunny in California. So, that's why I don't get it.

(Laughter.)

MEMBER SKILLMAN: Let me ask this: As you were B as you were forming this recommendation and

you're thinking around this, did you have briefings from any of the B

MR. SHEPHERD: Yes, we did. We had B

MEMBER SKILLMAN: Wait a minute, please.

MR. SHEPHERD: I'm sorry.

MEMBER SKILLMAN: Did you have briefings from the safeguards portion of a number of nuclear power plants on this issue?

MR. SHEPHERD: Let me see if I understand the question. So, safeguards folks from the plants themselves or B

MEMBER SKILLMAN: A couple of representative plants.

MR. SHEPHERD: Representative plants.

Kevin can address that.

MR. CROWLEY: This is Kevin Crowley again from the Academies.

We got briefings from NEI and there were industry representatives involved in those briefings, but we B we did visit some of the plants. But when we visited the plants, they specifically declined to talk to us about the details about security. So, it was done through NEI.

MEMBER SKILLMAN: Okay. The purpose for

my question is, my hunch is information that might have informed this recommendation was probably withheld not because industry was being coy, but because industry is prevented from disclosing that.

And I know for a fact having been involved in a lot of sites, there is a lot of preplanning and thinking for the question of what happens if we begin to lose infrastructure.

And I would simply comment the protections are very impressive, but they are not discussed anywhere outside of safeguards.

That might have been a valuable avenue to pursue and, if necessary, to pursue in the future under the right protected circumstances.

MR. CROWLEY: Well, one of the frustrations of the Committee, I might say, is although we were cleared to have access to safeguards information, we were not trusted, I gather, to have that information.

And so, we B I will fully agree with you. We suffered from, as you often do in situations like this, not having all the information. And I fully acknowledge that there are many things that are done in the industry that we were not exposed to.

But I would like to say that our recommendation was really pointed towards what the staff does in terms of their evaluation and their approach to terrorist threat assessment.

That's really what we were primarily focused on and that's what this recommendation is about; the US nuclear industry and US Nuclear Regulatory Commission should strengthen their capability for identifying, evaluating and managing the risk from terrorist attacks, and that means taking a more risk-informed approach to this.

So, for example, we can answer Joy's question about is this something that we necessarily need to worry about if you can put a probability on events or if you can evaluate these rationally in the context of a probabilistic risk assessment? Yeah.

You might say although this might be something of consequence, it has a very low probability, it's pretty far down on the event tree, for example, and let's focus on the things that are of greater likelihood.

But without having that capability, without having that risk assessment, without having some quantitative measure of that, it's very difficult

to make that judgment. That's what the Committee is saying.

MEMBER SKILLMAN: Thank you.

MEMBER BALLINGER: And I read the report for the first time yesterday. And so, I'm sort of coming at it from an outsider issue, if you will.

And would it not have been more prudent in the document based on the discussion we just had, to indicate that there are certain assumptions that you B that were made with respect to the security issue and the information that you had, and then say based on that information and with these caveats, this is our conclusion?

I don't know B I don't know whether that's stated in the document or not.

CHAIR REMPE: I didn't see a lot of caveats. And, again, that was why I was also asking about the gate performance. I think that some caveats might have been helpful.

MEMBER BALLINGER: Because it changes the whole tenor of the document when you say something like that. I mean, the implication here is, you know, well, there isn't enough.

MEMBER BLEY: Well, you know, they had B

they had access to the NRC B

MEMBER BALLINGER: Sure.

MEMBER BLEY: -- a lot of people from the NRC. The gate issue is something different than this.

MEMBER BALLINGER: Yes.

MEMBER BLEY: And as one member of this committee, I was rather pleased when I saw this in their report the first time. And it matches up with some of the things we've said over the years and related to this area.

MR. SHEPHERD: So, I'm sorry if the Committee left you with the impression that we did not find challenges in both understanding the material and also thinking through the challenges to how one would do this, but Section 5.4 in the report on page 122, the title of that is "Challenges for Applying Risk assessment to Security."

Because this is an area where a number of groups have thought about this not just in the context of commercial nuclear power, but DOE facilities and other facilities B I mean, there's been a whole cottage industry B maybe it's even, you know B

MEMBER POWERS: It's not cottage. It's up to a subdivision by now.

(Laughter.)

MR. SHEPHERD: I was going to say that.

(Simultaneous speaking.)

MR. SHEPHERD: The commercial industry rethought that, of looking at risk from terrorism over the last decade and a half.

And having been involved in some of those and being aware of those and a number of the members of the committees were, we understand fully that there are many different lines of thoughts and approaches to this. And we outline these here and we B in our discussion in 5.5, we recognize that there's a lot of work to be done.

In fact, the B we know that the staff is engaged in that work right now. And so, you know, I'm sorry that you're left with the impression, really, that somehow this was B we were downplaying things that are being done or the difficulty of it.

In fact, what we're really trying to do here is to encourage this effort to apply risk assessment to evaluating terrorist threats. That's what this chapter is about. And that's what the discussion says.

Even at this present stage of development,

security risk assessments can be useful for making relative comparison designs or operational alternatives. And this speaks to the issue that Joy brought up in terms of how much weight are you going to put on some of these things. And, you know, this is really where we come down on this. That's what it's about.

Okay. So, we got ahead of ourselves again. How much more time do I have left here?

CHAIR REMPE: I B you're scheduled until 10:00 B sorry. You're scheduled until 10:00, but I think that the staff, if we need to, their presentation -- you've come, and so we have a lot of questions about what your committee did. So, I'm not going to hold you quite to it. But if it gets to 10:15, I may cut you off.

MR. SHEPHERD: Oh, all right. Okay.

Well, what I'd like to back up then and do here is now that we've talked about this particular issue, is I'd like to back up and say what the balance of the report is about.

So, the B we talked about Chapter 2, and that was looking at lessons learned from what happened at Fukushima Daiichi and dwelled a great deal on Unit

4 and the design of the gates and so forth.

And in Chapter 3, we discussed the fact that the security infrastructure was impacted there and what implications that might have for the United States.

Chapters 4 to 7, that was part of the charge that we got from Congress was to go back and look at the 2004 and the 2006 reports. There were a number of issues that were examined.

And, in fact, one of the reasons why we were looking at terrorist attacks was because that was something we examined extensively in B particularly in the classified report.

Those of us who are involved in this business for a long time, can think back to what the atmosphere was like in 2004. The events of September 11th, 2001, were not too far behind and there were really extensive concerns about terrorism.

And so, that was one of the things that was focused on in the 2004 classified report. So, we reexamined what had been done since then.

We looked at the safety and security of the pool storage. That was something that had been looked at at that time.

There was an interest in the dry cask storage in comparison with the pool storage, and some issues of implementation of how the work gets done. And so, that really takes up Chapters 4 through 7.

And one of the things that we concluded, the Committee found that this Regulatory Commission had implemented most of the recommendation from the previous Academy's reports on spent fuel safety and security, for example, the dispersion of fuel after offloading and tracking fuel and so forth.

There were two things that the Committee felt specifically were not implemented. And those were findings 4.3 and 4.7.

One of the things that the Committee found useful, and I'll point this out, is on page 102 you'll find a crosswalk of the conclusions from the work that was done in 2004 and '6 in some -- in the form of a tabular form. And that tabular form compares what's in Chapters 4 to 7 with what was discussed in the earlier reports.

And then there were some very specific terrorist attack scenarios that were discussed in the classified report that we can't go into in open session.

And what we learned from our discussions with the NRC staff, was that those particular scenarios had not been pursued and analyzed.

So, that really is kind of in a nutshell, what the balance of the report is about, but there's some things that I think that we should continue to discuss. And that is some of the implications, for example, if you're going to use probabilistic risk assessment methods or carry out risk assessments of terrorist attacks, it's one of the things that should be incorporated. And when you do an analysis of spent fuel storage safety, is to look at the security risk. And so, that was our recommendation 4.1B.

And so, we felt that if you're going to develop a methodology for doing quantitative risk assessment, that that should be exercised. And a good place to exercise that is to look at the issues with spent fuel pool storage and also the dry cask storage.

And so, the question is, is can the results of that risk assessment be used? And one can imagine the outcomes of that could be, in some cases, very favorable for bolstering arguments about how to handle, for example, dry cask storage, which will become increasingly important in future years as we

continue to pull fuel out of the pool and place it in dry casks. So, that was one of the follow-on recommendations for suggesting using quantitative risk assessment on terrorist attacks.

We've already talked about 4.3. And so, now, finding 4.5, what is this about? Well, the B a very substantial amount of work has been done particularly through Sandia Labs, on looking at the effects of drain pools with hot fuel in them.

There have been a number of experiments that have been carried out now on PWR and BWR fuel using electrical heating to simulate decay heat, looking at the potential for having a fuel assembly to runaway oxidation, catch on fire, so to speak.

Then, analyzing that using extensions of the MELCOR code. And then applying MELCOR to analyzing loss-of-cooling and loss-of-coolant accidents in spent fuel pools.

The spent fuel pool safety study was B used that extensively as the tool for making the evaluations. And we B one of the things that we learned is that even if you reconfigure the spent fuel in the pools, the conclusion from those studies is it does not completely eliminate the risk of a zirconium

cladding fire particularly during a period of vulnerability just after shutdown.

And it also illustrated the importance of being able to maintain the coolant level or the cooling in the pool.

So, one of the recommendations that we have here is that B now, this is an extremely valuable tool. It's a primary tool that's being used to do these analyses that support the regulatory decisions. It's really B all of this work has very substantially improved the state of knowledge about spent fuel pool behavior, but there are a couple of areas that are of concern in terms of validation of the code in some of the key submodels.

One of those models I'll draw your attention to, and this is discussed in detail, and the chapter that deals with this is the spray modeling. Sprays are considered to be the primary means of mitigating a fully-drained pool.

And that modeling, we felt, had many aspects to it that were not sufficiently validated to have complete confidence in it. And so, we felt that that needed some work.

The other issue that we felt was really

very important is the problem of having a partially drained pool. You know, the situation here is that when you partially drain a pool, you have no potential for natural convection air circulation through the assemblies.

If you fully drain the pool, then you can bring in air from the bottom, the chimney effect, and natural convection and the air can potentially cool the fuel.

But if it's only partially drained, you're going to have evaporation and steam. The steam will possibly cool the fuel up to the point where it actually begins to oxidize it. And then one gets into serious trouble and has the potential not only for having runaway reaction, but also for generating hydrogen, which then could mix with the surroundings and potentially cause a failure of the structure above the pool.

And so, the partially drained situation is a challenging situation to deal with. We recognize that. But it's one that has not been really addressed or validated. And all of the work that's been done on experiments to date looks at the air cooling situation and the modeling is B modeling has been done on the

partially drained case, but there really is no validation for that.

And that is something that is probably the, I would say, one of the key areas that needs to be B

MEMBER POWERS: How would you envisage an experiment that would validate the partially drained B it's one big experiment.

MR. SHEPHERD: Yeah, that's an expensive sucker, Dana. I agree with you, if you do it in full scale.

One can try to be clever and think about subscale things, modeling portions of assemblies, but you clearly have to deal with the issues that B

MEMBER POWERS: And all that would happen would be that you would be here five years from now telling me, well, the experiments have been small scale up til now.

MR. SHEPHERD: We're always kind of stuck in that situation, aren't we, Dana?

(Laughter.)

MR. SHEPHERD: But we got to start moving the ball down the field, as they say in athletics.

MEMBER POWERS: Well, I mean, it's your

end-to-end validation. It implies that only a full-scale experiment is acceptable. I can't break the thing down into subexperiments and kind of add together things.

MR. SHEPHERD: We didn't try to specify how to do them.

MEMBER POWERS: And, well, that's your luxury of your B

MR. SHEPHERD: Well, I know. That is a great luxury of this type of committee.

MEMBER POWERS: But, you know, somebody is going to come down and beat on us and say, well, you have to do an end-to-end validation because the august National Academy of Engineers said you had to have B do an end-to-end validation, and this experiment doesn't look like an end-to-end validation. I mean, it's a peculiar set of words.

MR. SHEPHERD: What the Committee did in Chapter 6 B we're speaking here now of Chapter 6, loss-of-coolant events in spent fuel pools.

We looked at what has been accomplished since 2004, and it's quite substantial both in terms of the Separate Effects Tests that have been done at Sandia and elsewhere, and also the modeling.

And, you know, the B we did make this recommendation, 4.6, "The Nuclear Regulatory Commission should sponsor an end-to-end validation for use in modeling coolant loss in spent fuel pools, and validate key submodels in the code with particular attention to modeling the thermal and chemical behavior of spent fuel assemblies in partially drained pools; modeling the thermal and chemical response of spent fuel assemblies to the application of water sprays; modeling and validating for stratified flows in fully and partially drained pools."

We didn't specify the scale at which you had to do that. And I think certainly there's a good amount of engineering judgment, as you and I know, that's the key to success in this business. And I'm not suggesting we're going to go off and embark in a billion dollar exercise and taking the pool somewhere and B

MEMBER POWERS: Well, again I come back to we B

MR. SHEPHERD: -- burning up some fuel on it.

MEMBER POWERS: -- we certainly have a pretty good record on these fuels. It's hard to put

it high on the priority list.

MR. SHEPHERD: Well, again, this is one of the things that I think we came to at the end of the day and looking at the B what was done in the spent fuel pool study.

The spent fuel pool study was, as the staff rightly said in the way they described it was, it was, you know, deterministic analysis with probabilistic insights.

It was not a probabilistic risk assessment. And so, you know, placing a value on doing this particular analysis would require investing more effort in deciding if this is where you really needed to put your resources into.

CHAIR REMPE: So, because of time, let's go ahead.

MR. SHEPHERD: Yeah. Okay. All right.

So, we talked about 4.7 already. And 4.8 is a pat on the back. The B one of the things here, though, is that we B the thing that's really very clearly pointed out by all these studies, and looking at the spent fuel pool study, is there is a window of vulnerability after you offload the fuel because of the behavior of the decay heat with time.

And that window of vulnerability is really the critical thing in B when you look at analyzing if you're going to be getting into trouble and how quickly you'll get into trouble if you have a loss of cooling or a loss of coolant.

And so, right now there is a 60-day limit on fuel dispersion. And we think that's very laudable. And we think that's a great thing. Are there ways to decrease that even further?

I mean, one of the issues at Fukushima Daiichi was they were not doing this. If you look at that fuel distribution, it's absolutely horrific. They had all that fuel B hot fuel packed right in there together. It was B it was really a situation that was quite troubling.

And, you know, if it's possible to pre-position the fuel so that when you offload it that you're able to disperse it essentially immediately, the Committee felt that that would be a good thing.

MEMBER BLEY: When you looked at the spent fuel pool study, at least one of the things we found interesting there was complete dispersal wasn't always the best answer. They came up with some interesting schemes of having older fuel in there, the newer fuel

that provides even greater capability and B

MR. SHEPHERD: Actually B

MEMBER BLEY: -- I don't know if anybody has implemented B

MR. SHEPHERD: -- I think that's what we intended in terms of dispersal that if you have some heat-absorbing material in there as the older fuel does B

MEMBER BLEY: Yeah.

MR. SHEPHERD: Yeah. But what I meant by that is not packing any of the B of the B

MEMBER BLEY: Okay.

MR. SHEPHERD: -- hot B

MEMBER BLEY: Because they looked at cases where you really spread everything out, and other cases where B

MR. SHEPHERD: Right. So, we had a one-by-four and a one-by-eight and so on. And clearly, there's a benefit to having heat capacity in there. and we recognize that.

And so, really, when I say "dispersal," I mean it's not having the hot fuel adjacent to each other any more than possible.

CHAIR REMPE: So, in your last bullet, I

know we're short on time, but redesign the water makeup and spray systems to ensure they can be implemented when physical access to the pools is hindered, do we have a good -- there's a lot of uncertainties in -- how would you know you've redesigned it to make sure that it's going to be adequate?

Did you guys talk about that? Because that's something I was just curious about.

MR. SHEPHERD: So, I don't have the hubris to say I'm a, you know, design engineer for one of these plants. And, you know, we did have some folks in there with engineering experience, but, you know, we didn't feel it was appropriate for us to say what to do there.

It's just we felt B and this really goes back to our earlier discussion about if you're going to have sprays, how are you going to make sure that you can actuate the sprays and get them working?

CHAIR REMPE: But you've noted there's a lot of uncertainty in those models. And so, I guess you first need to resolve that uncertainty before you redesign the system, right?

MR. SHEPHERD: There's a lot of work to

do.

CHAIR REMPE: Yeah. Okay.

(Laughter.)

MEMBER KIRCHNER: Joy, I had just observed that there's been an awful lot of work done on spray cooling of fuel, not for this purpose B

CHAIR REMPE: Uh-huh.

MEMBER KIRCHNER: -- but any of the designs with upper head injection. And other techniques for recovering from the LOCA have worried about this problem for years and years.

You're talking about very hot fuel trying to get water back in and such. There's quite a body of literature out there on spray performance for fuel bundles.

CHAIR REMPE: Okay. And your group was aware of this?

MR. SHEPHERD: Our group was aware of this. We looked at the MELCOR theory manuals and the basis for the spray models. And we felt that those spray models could certainly be further examined and improved.

MEMBER POWERS: Well, the spray modeling in MELCOR is not at all comparable with what Walt is

talking about.

MR. SHEPHERD: So, it may be as simple as incorporating that knowledge and putting in a model which, you know, includes what's been learned from these experiments.

MEMBER POWERS: It's a clearly different situation.

MR. SHEPHERD: Yeah. It's a pretty primitive model, in my opinion.

MEMBER KIRCHNER: Actually, the denser the packing of the fuel, the more relevant the model B

MR. SHEPHERD: Yeah. Absolutely.

(Simultaneous speaking.)

MEMBER KIRCHNER: -- and recovering from a LOCA.

MEMBER POWERS: It's the physical stuff that kind of independent B the more fundamental problem is that if you're looking to address an event that is sufficient magnitude to damage the plant itself and preclude entry, anything you design in there has also gotten damaged. It's almost assured that it's gotten damaged.

And so, developing a strategy as to pre-positioned piping sprays and things like that seems

like a fool's errand to me, because you're hypothesizing a situation in which you have not only damaged the pool systems, you've damaged the plant and you've hindered access to the site.

That's a pretty formidable event. We know they can occur, but B

MR. SHEPHERD: Fukushima was pretty formidable, but I respect what you're saying, Dana. And this certainly B one has to consider the value.

Kevin, did you want to B

MR. CROWLEY: Yeah. Kevin Crowley from the Academies again.

Just B the conversation has marched on a little bit, but just to respond to Joy's comment that she made earlier, you know, have you thought about what would need to be done with respect to the second bullet, I just want to remind the group that what the Committee was doing here was reevaluating the findings and recommendations from the 2004-2006 report.

And in that report, there was a recommendation made for a provision for water sprays that could cool the fuel even if access to the pool was restricted.

And I can remember the discussions that we

had particularly with industry when we were rolling out that report where we were basically dismissed and they said, "You know, we just can't imagine a scenario where we couldn't get up on the pool deck," and here we are.

And, you know, I think that at least in my discussions with the Committee, that sort of tempered the discussions that the Committee had. It's very hard to envision the kinds of scenarios that you might encounter. And so, you really need to have a flexible approach to be able to get to the pool and restore water or spray.

And I think that was illustrated very well by what the group at Fukushima actually ended up doing. They tried a lot of different things, and then they eventually found something that worked. And so, I think there's a lot that we can learn from that.

I don't think we need to understand every potential scenario, but certainly based on what happened at Fukushima, we have a pretty good idea of what the maximum kind of damage might be and what we might have to overcome.

And based on that, then, we could design some flexible approaches to restoring cooling or

spraying that might not only involve pre-positioned equipment, but might also involve having equipment staged or nearby where you could bring it to the site and use it like they did with the concrete pump trucks.

MEMBER POWERS: Yeah. We usually call that FLEX.

CHAIR REMPE: Let's go ahead, because we're going to run short on time.

MEMBER POWERS: Joe, could I just ask you one question kind of off the wall a little bit here?

MR. SHEPHERD: Yes.

MEMBER POWERS: During the course of the accident itself, we were inundated with recommendations sincerely made that we pour sand in onto the spent fuel pool to stem this raging fire that was purported to occur in every press report.

And of course we fought vigorously to try to explain to people this was probably the last thing on God's green earth we wanted to do.

Were you aware of those heartfelt suggestions that were flooding into us, and did your B was there reason not to make comment about the folly of that idea?

MR. SHEPHERD: Well, you know, I spent four years immersed in the literature of Fukushima, both the technical and the nontechnical parts. And so, I was aware that there were a lot of cockeyed proposals and concerns.

The Committee did not try to address those, Dana. There was only so much time in the day.

MEMBER POWERS: Sure. Sure. But, I mean, it was, you know, you would write a refutation and say, no, no, you definitely don't want to do this. And it would, like the Hydra, emerge from those ashes more heartly felt, I mean, and from moderately prestigious sources and people that really ought to know better.

MR. SHEPHERD: It's challenging doing realtime accident management. There's no denying that. That's a tremendous challenge.

And as, you know, as technical people, we always struggle with how to communicate the viewpoints that we feel are rooted in the technical facts of the matter using our empirical knowledge and critical thinking and logical reasoning, which is where we B I always try to come from, but not everybody goes down that path.

All right. So, we looked a little bit at the dry cask storage. And in the process of looking at that, we learned that the rulemaking that was ongoing was going to be delayed.

And so, we B our only recommendation is we felt it's very important to follow that through and bring that to completion.

Finally, I want to comment here on the spent fuel pool study. And we've talked about this a bit already in the context of doing risk assessment for terrorism and also commenting on the fact that the spent fuel pool study was not a qualitative risk assessment, although it did use insights from that.

And what the Committee felt was that, really, that there needed to be an analysis, and that's what our recommendation was B

CHAIR REMPE: Before you leave that 4-11, are you planning to talk a little bit more about what that text has in it? Because you've inferred that the NRC models aren't considering certain health consequences and B

MR. SHEPHERD: Right.

CHAIR REMPE: -- if I look through the report, the only health consequence that I could see

you call out explicitly was the need to consider psychological effects.

Is there anything else your committee talked about that needs to be considered that's not being considered by the NRC other than psychological effects?

MR. SHEPHERD: Well, the B some members of the Committee had significant concerns about how the boundaries were set on that evaluation. And I understand that there are regulatory and legal boundaries on that.

The Committee was looking at lessons learned from Fukushima. And some of the things that we learned from that is that, you know, the B one can have, you know, modest amounts of B what you might think of as modest amounts and limited amounts of contamination, yet have very severe effects on the society that is in and around those areas.

And we felt that it would be important to look at what the outcome was at Fukushima and to think about what was being done in terms of those analyses.

CHAIR REMPE: But, again, the answer to my question is that, yes, it was only psychological effects. You didn't B there wasn't anything else that

you guys found that was deficient in the way NRC looks at health consequences; is that true?

Because it's kind of vague and I had to dig to come up with B

MR. SHEPHERD: Kevin is going to help me clarify the meaning of that.

MR. CROWLEY: Kevin Crowley again from the Academies.

I would use a slightly different word. I would use "psychosocial effects." I mean, there are psychological effects, but also if you look at what happened at Fukushima, it had a real impact on community structure, for example. So, it goes beyond how people think or how people feel about things.

CHAIR REMPE: Okay.

MEMBER POWERS: And you're able to distinguish one from the tsunami that had a very, very substantial effect on the social dynamic?

MR. SHEPHERD: So, you know, when you do these kinds of studies and lessons learned, one is always confronted with this issue, Dana.

And, you know, our job was limited and we focused on this and, you know, certainly if you're looking at risk to a society, for example, if you

would propose to do a risk assessment on should we live on the Island of Honshu, you might think about that, but that wasn't our job.

So, then I'm going to skip over some material in the interest of time here, which just is really explication of what we had gone through in Chapter 7.

Chapter 7 is really a precis of our analysis that the Committee did on the expedited transfer decision. And not the decision itself, but really the basis for that.

And our recommendation was that we felt it was a very valuable study, but we felt that there were, for one thing, what really needs to be done is a quantitative risk assessment and it needed to include in a comprehensive way, the risk associated with sabotage, dry cask storage and, as we've been discussing, these health consequences.

And that, we believe, will enable having B to be able to assess this issue in a level of thoroughness that B

MEMBER POWERS: Well, I mean, I just had to really take issue with you. You know very well that people are unable to assess sabotage risk

technically. Now, why make a recommendation to do the impossible?

MR. SHEPHERD: Well, Dana, we actually spent some time talking about that, you know. We have a B Chapter 4 here has an extensive discussion about that.

It's B I think it's a topic on which reasonable people can disagree and it's worthwhile thinking about it.

MEMBER POWERS: It's always the initiating for this. How do you B

MR. SHEPHERD: We have a B we have a discussion about that. There are approaches that you can use to that using things like expert elicitation. One can rely on databases of events.

This is something that people are thinking about. We're not suggesting that it's easy. And as we acknowledge, you know, there's a lot to be learned about it, but, you know, the question is, are we going to take this attitude from here forward that we're going to throw up our hands and say, "There's no way to estimate these initiators, so we're not going to deal with it"?

The Committee felt, no, we need to

confront that and try to figure out what we can do. We're not suggesting necessarily we have the solution at all, but let's move forward with it, thinking about it, how to do it in a more sophisticated way.

I can see we're going to disagree about this.

MEMBER POWERS: I don't disagree with you at all. It's worthwhile to move forward. I think I would have made it a softer point. You can't do this right now, why don't you spend some time figuring out how you can interface security and ordinary risk assessment in some way that you can do a better job here rather than think and coming in and say, "Well, just go do this," because it's not just go do this. It's B

MR. SHEPHERD: Wait. Wait. Wait.

MEMBER POWERS: -- not like people haven't tried.

MR. SHEPHERD: Wait. Wait. Wait. Wait. Wait. That B we didn't say what you said. We did acknowledge.

And if you look in Chapter 5, we said very clearly what you really need to do is you need to start this process and learn something about how to do

it.

MEMBER POWERS: Well, I think that's -B I think that's your recommendation.

MR. SHEPHERD: Yeah. In our discussion, we say the present committee is acutely aware that it's finding 4.1 -- this is the one we're discussing about security risk assessment B- is a substantial departure from the previous conclusions of other NRC committees on the use of risk assessment and security applications. And this finding is intended to encourage the massive efforts by the USNRC and nuclear industry to develop security risk assessment, also to encourage further development and application in the broader risk assessment community.

That's where we come down on this. So, I couldn't B I couldn't agree with you more.

MEMBER POWERS: Yeah, I just B-

MEMBER BLEY: You know, you don't -B you don't really advance to this B-

MEMBER POWERS: -- I just object to the wording of the recommendation. I would have had two recommendations here were I doing it.

MR. SHEPHERD: We spent probably, I don't know, 24 months arguing about every damn word in this

thing. And I have to tell you B-

(Laughter.)

MEMBER BLEY: But to Dana's point, I haven't found that you really advance in these kind of areas by sitting around thinking about it. You advance by trying to do it, digging in and failing and trying again. And if you don't start, you're never going to get there.

MEMBER POWERS: There's truth in what you say.

MEMBER BLEY: Only a little, but some.

MR. SHEPHERD: And with all that, I believe I'm out of time unless you B-

CHAIR REMPE: If there's anything else -B I know you have a couple more slides and I will give you a little flexibility if there's a burning issue that you wanted to talk about.

MR. SHEPHERD: Just a pat on the back and B-

(Laughter.)

MR. SHEPHERD: -- just a summary of what we've already gone through. And so with that, I'm through.

CHAIR REMPE: I appreciate you coming and

listening to our questions and answering them. I know it's contentious, but it helps to have your viewpoint of what went on.

MR. SHEPHERD: Well, no, you know, I believe that a lot of very good observations have been made.

It's a very challenging problem. It's -B I think there is a lot of work to be done and I think it's very right to recognize that it's important for the staff and this committee to consider this in the context of the world that you live in, the regulatory space as it's set up around here. So, thank you all.

CHAIR REMPE: Okay. So, with that, we're going to still have our break, but let's still plan to come back on time at 10:15, because we do have full committee meeting this afternoon. So, we're recessed.

(Whereupon, the above-entitled matter went off the record at 10:04 a.m. and resumed at 10:16 a.m.)

CHAIR REMPE: Okay, we=re going to turn that mic on and reconvene. Okay, folks? And who from the staff will go first? Okay, go for it.

MEMBER POWERS: Because he so much loves being here before us.

(Laughter.)

MR. RECKLEY: Hi, my name=s Bill Reckley, Office of Nuclear Reactor Regulations, the Lessons Learned Division. We actually have a fair number of staff here because, as you=re aware, it was a kind of diverse report with different people.

So, sitting at the table was Joe Rivers and Hossein Esmaili. But also, here, Steve Jones, Eric Bowman, Fred Schofer, Pete Prescott and Keith Compton.

So, I think we have subject matter experts here for a variety of topics. And I won=t comment on -- when we drew straws -- whether the short straws were the people at the front or the short straws were the people in the back.

(Laughter.)

MEMBER POWERS: We will insist on documentation of that particular move.

MR. RECKLEY: This was already gone over in some of the background on the study. As was the fact that it was done in two phases, with Phase I looking primarily at reconstruction of the accident, and safety insights.

And Phase II, looking at security matters

and spent fuel pool storage and the evaluation of the 2004/2006 Academy study. I=ll add that the staff=s assessment of the Phase I report was in SECY-15-0059.

It was in enclosure six. That was one of our periodic six-month updates to the Commission. The more recent Phase II study was addressed in SECY-16-0100.

While I=ve got this slide up, I would like to mention that, when you=re looking at it from the staff=s viewpoint, we=re looking at it collectively.

And so, sometimes you can look and say, well on Day 4 at Fukushima they had this issue and this might have helped, right? But we=re looking at it also from the perspective of we=ve taken measures to address core cooling.

We=ve assessed hydrogen, hopefully to prevent the major cause of the problems at Fukushima, in regards to the spent fuel pools, which was the hydrogen explosions, not the initial seismic event.

And so we=re looking at it collectively and not necessarily arguing that at Fukushima this might have helped or this is what happened. But how that fits into the overall regulatory response, collectively with all of the actions that we=ve taken.

MEMBER POWERS: Do you examine intensively and carefully this predilection, apparently, that must exist for terrorists and malevolent individuals to flood into a nuclear power plant site that=s undergone an accident and is releasing radiation over the countryside? Is that a major focus of your attention?

MR. RECKLEY: Well, given it was one recommendation, we did think about it. And we=ll get to it later. There are natural events that have happened here, that have given us insights.

And hurricanes are actually in the United States, one that happens periodically where we have to assess. There=s a natural event that=s going to impact the security of the station because -- just because of the event.

And what contingencies are put in place and how we respond. We=ll get to it later, but the other thing to keep in mind as you compare what happens at Fukushima or any other plant around the world is, they start from a different place and security than U.S. plants do.

And so, the amount of time that they took, potentially to recover, or the attention that they gave security starts with a difference from the

beginning.

Their plants have a different security structure and I think Joe can weigh in. But I think it=s safe to say American plants are probably among the more secure in the world.

So, with that, we can get into the specific recommendations. And, just what I=m going to ask the staff, I=m going to go through basically the bullets.

But if there=s questions, or if any of the staff want to weigh in from the table or from the sides. Recommendation 2.1 in the study basically called for improving beyond what we=ve done, the ability to monitor the pool and to provide makeup to the pool.

We do, just in the SECY paper, SECY-16-0100, point out this is a similar recommendation. Actually, it=s a similar recommendation than we got from the ACRS in the early days of the accident.

Or, in the early days following -- in addressing the lessons learned. We did consider other instrumentation. Temperature is the one that most often is mentioned, although area radiation monitors also.

And have concluded and, even after assessing it again, in response to the National Academies report, believe that the level instrumentation that we did require through Order EA-12-051 and the pending rulemaking is sufficient to address the lessons learned.

I=m not arguing that maybe it wouldn=t be better to also have temperature in area radiation monitors and all of that stuff. But as someone pointed out, we have to look at it from a context not only of what would be better, but could you actually justify -- when=s enough enough.

When=s enough in terms of backfits analyses and how much money we=re going to require to be spent to address an issue. In regards to makeup to the pool, or sprays to the pool, that really was initiated first through the B5B orders, the 9/11 orders, was picked up in the Rule 5054 HH.

And then enhanced through the Fukushima lessons learned, to look at it from not only loss of large area of the plant due to fire and explosion, but looking at it from other events such as seismic or flooding.

And so we came to the conclusion that

additional requirements for instrumentation or makeup capabilities beyond what was imposed through the order and the pending rulemaking would not provide a substantial increase in the overall protection of public health and safety, which is the language out of the backfit rule.

CHAIR REMPE: So, I have a lot of questions that are more on the technical details. But -- and I guess this is a good time to bring them up, since it=s pertaining to this?

First of all, this issue about the gate performance. What does the staff know about the way a Unit 4 gate would have performed in a U.S. plant in the way the U.S. plants are designed?

If you had a situation where you were refueling, and you had a differential in the water level, would you see end leakage? Is that the expected performance of the gate?

MR. RECKLEY: And I=ll let Steve weigh in. I=ll give you my own feel. These things are designed -- and I think it=s a similar answer you got from Dr. Shepherd.

They=re designed to keep water into the spent fuel pools, right? So that=s what their design

is. When the pressure differential goes different than what the design was, you may have leakage.

Whether people gave that forethought that that was Aby design@, I=m not sure. Steve might have a view.

MR. JONES: This is Steve Jones, Office of Nuclear Reactor Regulation. First of all, I=d start with this configuration at Unit 4 was unusual for a -- it would be unusual at a U.S. plant.

Normally during refueling, the gates are not reinstalled. And you would have the cavity flooded and communication between the spent fuel pool and the other cavities for the entire refueling outage.

The one exception may be during in-service inspection of the reactor vessel, things that would require a dry access to the vessel. And, in that case, you wouldn=t have the ability to re-flood the pool from the reactor cavity area.

CHAIR REMPE: So, if they=re wide open, then if one were trying to do some sort of cross-benefit analysis, it would be a much shorter time period where you would ever see some sort of difference in water level?

MR. JONES: Right. And then, I did want to mention that that gate configuration is pretty standard among the older BWR plants, where you have two elastomeric sealed gates with a leak off in-between that indicates any leakage from the spent fuel pool into that reactor cavity area during operation.

And during refueling that=s, of course, closed.

CHAIR REMPE: Okay.

MR. RECKLEY: So the way we tended to look at this was whether you are assuming that configuration and a window and a refueling outage where the leakage comes from the well into the spent fuel pool.

Or the opposite, where you have leakage from the spent fuel pool because of a leaking gate or a leaking seal out of the spent fuel pool into the cavity or into a transfer canal or whichever -- depending on the plant that you=re talking about.

And we tended to look at it and say -- acknowledging that might occur in some of these events, would it lead us to do anything in addition to what we=ve done, in terms of providing makeup to the pool and doing any additional monitoring other than

the spent fuel pool level instrumentation that we=ve required to install.

And the conclusion we reached was no. The things that we=ve done can address those issues and we wouldn=t require anything in addition, even looking at it.

CHAIR REMPE: Just, also for my education on the Unit 3 configuration, when you=re in operation and they=re concerned about the damage to the gate at Unit 3.

My understanding is that they have put water in the spent fuel pool at Unit 3 and even though they=ve said, well it=s hard to get good information, it=s holding water.

So, I don=t think that the damage is significant enough that it=s leaking. But the other question that they brought up was this 1997 report where there were some findings in the past about gates not holding during normal operation.

And my understanding is that, when I reviewed that report, it was human error, installations done well, and those issues were brought up to the Commission.

And did the plants take action to resolve

them?

MR. JONES: Yes. This is Steve Jones again. There have been several changes. Most of the events that resulted in, significant leakage were related to seals that failed due to loss of instrument air for the inflatable seals that are common in the BWR plants.

And, for example, one of the largest leakage events occurred between two units where there was a transfer canal that was temporarily flooded. And one of the seals allowed water to leak out of the pool area and into a drained area.

But there have been a lot of improvements made to the reliability of the pneumatic seals by installing air bottles as backup supplies of air. And, in general, better operator performance throughout the industry.

We routinely monitor operating experience, looking for reports or inspection findings related to loss of water from the pool or similar types of events that were reported in that 1997 NUREG.

And we=re not seeing anywhere near the rate that was reported in that NUREG.

CHAIR REMPE: Okay.

MR. RECKLEY: I=ll just throw in -- I mean, that=s generally true of that whole NUREG-1275 series, keeping in mind that it was capturing the operating experience of the first 20 years basically.

And so, not matter almost which of those volumes you look at, performance is better now than it was as it was captured in those reports, just because that was then.

CHAIR REMPE: How many plants have implemented the dispersed configuration that was recommended in the Spent Fuel Study? I mean, it=s not been required by the plants --

MR. RECKLEY: The one-by-four?

CHAIR REMPE: Yes. I mean, your study recommended having some sort of dispersed configuration --

MR. RECKLEY: Yes, the action we took was -- they all do the one-by-four. The going to an even more dispersed like a one-by-eight, as was mentioned in the Spent Fuel Pool Study -- We issued an information notice.

CHAIR REMPE: Yes.

MR. RECKLEY: I would be surprised if anybody=s done much by now. Although, some are

already done. I mean, that model was picked up because Peach Bottom already did that configuration.

But, to be honest, we don=t have any reporting mechanism to know who else might do it.

MEMBER BLEY: Bill, not all our members were here when we looked at that.

MR. RECKLEY: Okay.

MEMBER BLEY: You might tell people what one-by-four and one-by-eight means.

MR. RECKLEY: Okay, the one-by-four is a hot assembly, surrounded on each major face with a colder assembly. And a one-by-eight is a hot assembly, surrounded all of the way around by a colder assembly or an older assembly.

CHAIR REMPE: I mean, there were some recommendations about where you need to improve the modeling. And I know, later, you=re going to talk about what you are doing with MELCOR, in your slides, because I looked ahead.

But, is that something that you want to talk about here, or would you rather talk about what will be done with --

MR. RECKLEY: If it=s the modeling, it=s just a couple of slides from now. If we can wait?

CHAIR REMPE: Okay, okay.

MR. RECKLEY: So, moving on to some of the security-related recommendations in the NAS Study. 3.1 involved the recommendation that security be enhanced to deal also with the beyond design basis external events.

We just simply point out in the SECY-16-0100 that security systems do have redundancies, backup power supplies of their own. So there is some redundancy there.

We point out that, although not necessarily designed for it, FLEX would remain available and could help in security-related events, in addition to natural events.

There has been, since Fukushima and as an add-on to really what was done after 9/11, much better coordination between licensees and local and federal agencies.

As I think was pointed out by Dana or someone, we also think that a security event coincident with, or taking full advantage of the natural disaster, is unlikely.

And then, as I pointed out earlier, the United States and U.S. plants do have a different

structure and a different emphasis on security, such that we don=t think that it would be as long as it was at Fukushima, before a security response is put back in place.

MR. RIVERS: We don=t necessarily run exercises focused on a natural disaster, but one of the roles I play in the Emergency Operation Center is actually as the Deputy Director of the Safeguards Team.

And so, as events are unfolding, we=re constantly looking to see what the current security posture is. Whether there might be weaknesses. Do they have compensatory measures in place?

And so, we have a whole team here, and the region has people also looking at it to make sure that if there are issues that are impacting security, that we immediately get something in place to protect that facility.

We also work with identifying other state, local and federal resources that might come into play. We have other activities besides emergency exercises, like an integrated response program that works with federal, state and local law enforcement, in the event that there is an attack.

And we try to coordinate the response for those protections of the facility. We work very closely with a lot of our sister federal agencies to make sure that we all know if something happens, what can be done.

MR. RECKLEY: So, the conclusion then is, with all of that in place, current practice and requirements, we didn=t think an additional regulatory requirement for changes to the security systems at the U.S. plants was warranted.

Recommendation 4.1A was to strengthen the integration of risk assessments into the security -- or, maybe I should say it the other way -- to integrate security into the risk evaluations.

We -- I think, as we=ve pointed out before in meetings, that ANSR has taken the lead with another subcommittee of the ACRS. There are ways that risk assessment techniques are brought in to the security arena and they=re exercised.

That=s done in cooperation with other federal agencies, Department of Homeland Security and others. It was done extensively after 9/11, looking at the requirements that we put in place through those orders and that rulemaking.

Including how to manage the interface between safety and security. To me, anyway, up until 9/11, there was always kind of a more clear line between those two things.

And one of the lessons that I think we did draw from 9/11 was to look at those things together and to make sure they worked together. That one didn=t undermine the other.

And again, there=s been discussions with ACRS about those. Joe can weigh in on some of the ongoing activities. One of those activities is, at least for new plants, there=s been a revision to the Advanced Reactor Policy Statement that basically encourages designers to bring in security issues from the beginning.

Security by design, as opposed to designed the plant and then overlaying security onto it, kind of as an afterthought. Before I get to that last one, I don=t know, Joe, do you want to weigh in?

MR. RIVERS: I=ll weigh in on a couple of things on this slide. One, is the work we do with other federal agencies. And probably the biggest effort underway, to look at terrorism, risk assessments, is essentially out of the Department of

Homeland Security.

And they have an integrated terrorism risk assessment which looks at rad, nuc, bio and chem. And we weigh in very, very heavily into that process. We get involved in, even the likelihood attack elements of it as well.

And then, what can happen if a terrorist attack actually takes place. When we look at what=s going on within the industry itself, probably over the last several years, I worked very hard to encourage the utilities to actually purchase modeling and simulation software, very similar to PRA software, but for security, to try to better understand the risks associated with a security event at their facilities.

My guess right now is that probably well over half of the sites in the United States are now starting to use that software or have been using it for years.

We=ve had submissions for security plan changes that are supported by that modeling and simulation software -- the analysis that comes out of it.

With the help of the Institute of Nuclear Materials Management, we=ve actually conducted

workshops to try to help bring the industry up to speed on how to use these tools, what they can be used for, how they can be incorporated into regulatory framework.

One of the workshops actually, about a year or so ago out in Idaho, we actually worked in conjunction with the American Nuclear Society to put on a workshop where we brought safety and security risk professionals together to talk about how each can leverage the other=s analyses in support of their own risk assessments.

But, I think, over the last two or three years, we=ve made a lot of very big improvements in how our licensed community actually assesses risk at their facilities.

MEMBER BLEY: Joe, it=s been almost a year since you guys came and told us about the work being done in vulnerability assessment. At that time, you had five or more submittals. How have they fared through the review process?

MR. RIVERS: I think they=ve fared fairly well. I think initially, any time industry is doing something new, they=re trying to figure out, how much information do they really give us in the submission.

And so we had some submissions with very little information. One submitter saying we used a computer model for further information. We had others have went a lot further.

And so, I think through an iterative process, I think we=re getting to a point where they have some understanding of what we would expect to see in those submittals.

And so, I think as we move forward we=re going to see a lot more of that.

MEMBER BLEY: Another area I=m interested in is -- we=ve heard, and I know there=s no application yet from NuScale -- but, apparently, they are tying security and safety tightly together in their application.

Have you guys had a chance to think much about that, or been involved in that?

MR. RIVERS: I=ve heard from those that are supporting NuScale that they=re supporting NuScale and those activities. I have not seen any of the products.

MEMBER BLEY: Okay. We=re looking forward to seeing something there. But I=ll wait for an application, I suppose.

MR. RIVERS: But I think that gives you the indication that there is a lot more momentum moving in the direction of trying to use risk information to support security in the license industry.

MEMBER BLEY: So, in response to the National Academy report and their recommendation, I hear you guys saying, yes you agree with Recommendation 4.1A and you=re moving in that direction?

MR. RIVERS: I would say that=s correct, right.

MR. RECKLEY: That=s the conclusion, but I don=t want to overstate it. We were doing things in that area, and we=ll continue to do them. But we=re not redirecting resources directly as a result of the Academy=s report.

MR. RIVERS: No, this is activity that we=ve had underway for years now. And some of it=s in the background. Part of what I noticed when I got here was that I probably would be very challenged to write requirements and regulations to get industry to do this.

So it was much easier to work with

industry to convince them that there are things that would benefit them to do this as well, because of my experience and working in the Department of Energy environment, where these tools were used routinely.

And that was somewhat of a surprise when I got to NRC and I saw no use of those tools. And so, I think industry is starting to see the value of these tools for their own operational activities, as well as supporting the regulatory activities.

MEMBER POWERS: Just a clarifying question. So, you see no need to accelerate? You feel you=re at a proper pace?

MR. RIVERS: I think given what it takes -- one of the issues you always have to look at, and the industry=s starting to use these tools, is okay in the Department of Energy and the Department of Defense, they call in the National Laboratory resources to help them do the modeling, help them do the analysis and all of that.

Our industry doesn=t have that capability. So what you find is that some of them are trying to build up that in-house capability. Others are hiring some people to formally work at DOE facilities to have that expertise to be able to do that analysis.

We can=t really make it happen overnight, because there=s roughly 65 nuclear power plant sites and there=s only so many experts out there. So I think we need to give some time for that expertise to build up.

CHAIR REMPE: So, I=m involved with some other DOE activities and they have this LWRS sustainability thing that helps with subsequent license renewal.

Have you ever talked to the Department of Energy to try and have some of that funding allocated to the health industry?

MR. RIVERS: I don=t think that=s really my role.

CHAIR REMPE: Yes, that=s probably true. But it sure seems like that would be an opportunity that would help.

MR. RIVERS: Yes. But I think the organization that probably can promote that a lot more is the DOE Office of Nuclear Energy.

CHAIR REMPE: Yes. But there=s an MOU in our CN DOE, and DOE wants to allocate resources appropriately. And I think that might be something that might be of interest.

Again, I=m not into politics on how to get that message to DOE.

MEMBER BLEY: Things are really bringing -- and I know there have been several SRMs from the Commission that talked about bringing safety and security together.

We=re really coming that way, and risk tools are being used. Has the staff given any thought to bringing any of this analysis approach to this committee?

MR. RIVERS: Probably not. I get pretty busy. I do a lot more than just looking at the risk aspects of security as well. So, I=m only one person, so --

MEMBER BLEY: I understand. I think it=s an area where we might be of some help.

MR. RECKLEY: Okay. The only other bullet on this slide is the NAS study, it talked about asymmetric threats, which were not necessarily threats directly against the facility, but against power lines or something that could affect the facility but it wasn=t a direct assault on the facility.

And our observation is to acknowledge that, but to basically say that the plants are

designed from a safety sense to deal with those kinds of events.

And then, the conclusion here that, as we mentioned, things are continuing. To some degree, as Joe mentioned, it=s kind of up to the industry how much to adopt.

And we=ll react if the industry starts to say, hey we want a whole bunch of changes to security plans based on insights from the risk assessment tools.

Then we=ll gear up to assess to that. But, in the absence of an industry initiative, it=s kind of hard for us to push them in that direction.

MR. RIVERS: And, in reality, a lot of the changes they=re looking at are not necessarily stemming from actual use of the tools, but the use of the tools supports their conclusions.

And I think that=s really what we=re finding.

MR. RECKLEY: So, Recommendation 4.1B was a recommendation for the NRC to sponsor a spent fuel storage, including the pools and dry cask storage from a security risk assessment vantage point.

We point out in the SECY that we do

cooperate and share information with other federal agencies like DHS. We also participate in IAEA activities that are related to enhancing or improving the assessment of security at plants and in spent fuel pools.

Again, a lot of activity was done in the aftermath of 9/11, where we looked at PRA-like insights, in terms of the security at plants. Not necessarily -- and Joe can weigh in -- but not necessarily assigning a frequency or probability to the initiating event.

But given initiating event, what was the plant response and, in terms of security, to a particular threat using PRA assessments or vulnerability assessments or whatever terminology you want to put on.

But those have a risk insight PRA-type approach built in make the observation that this is a very similar recommendation from 2006. And the NRC=s basically coming to the same conclusion, that we don=t feel a need to change course from the path that we=re on, which includes trying to do what NAS is recommending.

MEMBER CHU: Question. There are a lot of

talks about getting interim consolidated spent fuel dry storage facility. Now, if some entity came forward with the intention of design and built one of those, would that entity know what other requirements related to security?

MR. RIVERS: Basically, we have lots of situations that are ongoing right now where we don=t necessarily have absolute security requirements. For example, one of the things is the moly-99 facilities that we=re engaged with right now.

We really don=t have regulations that strictly tell you how to secure a moly-99 facility. So, we work very closely with, essentially, the licensing organization, NRC, to work with the industries so they have some indication as to what the security requirements would be.

So we do have some ongoing rulemaking activities that, if we=re successful in getting them out, it would focus really more on the material form and the material, not necessarily how it=s being stored or used or whatever else.

And so, if we=re ever successful in getting that rulemaking through the process, then a lot of this -- the question, I=ve got a new type of

facility, I wouldn=t have to worry as much about how I would secure a new type of facility.

I know what the material is in that facility, so I know how to secure it.

MEMBER CHU: So you=re going to wait until something happens and you=ll work with that entity?

MR. RIVERS: Well, if we don=t have something in place right now, we work with that entity to make sure they understand what the security requirements will be.

We do have ongoing efforts to actually try to establish a rule that would essentially cover almost any type of activity that could take place with material.

MEMBER CHU: Thank you.

MR. RECKLEY: But there established requirements for an ISFSI?

MR. RIVERS: Yes, there are.

MR. RECKLEY: And we started down that path before, with private fuel storage and others. So, there has been thought given to the security of a dry cask case.

MR. RIVERS: And we have a number of independent spent fuel storage installations that are

separate from nuclear power plants, typically of decommissioned reactors.

And so, we have a set regimen of what security is expected of a facility like that.

MEMBER CORRADINI: That would be a place to start looking if --

MR. RIVERS: That=s correct.

MEMBER BLEY: I=m curious, before you leave this one -- research is in the midst of maybe nearing the end -- we don=t know quite yet -- of a state-of-the-art level 3 PRA of complete nuclear power plant facility, including spent fuel and the works.

Has there been any thought of possibly extending that into this area sometime in the future?

MR. ESMAILI: What I heard from -- this is not our area, but what I heard from level 2 PRAs that any security=s out of scope.

MEMBER BLEY: Well, it is for the work they=re doing now. My question was, has there been any thought to, in the future, extending that study to include the security area.

Because it will be an NRC PRA of a complete facility level 3. It would be a nice place to begin.

MR. ESMAILI: I don=t know the answer.

MR. RECKLEY: We=ll take that away as a -- moving on then to Recommendation 4.3 in the report, which is to obtain an independent examination of security measures for protecting spent fuel.

And as was mentioned before, this is a carry-on from the post-9/11 NAS study that was documented in the 2004 and 2006 reports. I think we tried in the report to, first of all, convey a message that the NRC is an independent agency.

And so, the hints that we should always go get something independent from the industry and the NRC is -- I understand the recommendation, but it does hit a nerve once in a while.

So, we spend a few paragraphs talking about our independence and the oversight that we get from the Congressional oversight bodies, as well as our own office in the Inspector General and the General Accounting Office.

That said, we also look for operational experience from inspections, the drills and exercises that we do, international activities and public interactions and those.

I know that=s not quote an Aindependent

assessment@, but that=s a very valuable tool that we use to see whether the programs that we have in place are working, when you=re measuring it against actual operating experience and drills and exercises.

MR. RIVERS: I would comment one thing too on this. Our insider mitigation program at NRC is -- we=re constantly being asked by other federal agencies to promulgate how we actually performed that insider mitigation process and how our licensees do that all around the world.

We have people that are essentially paid for by other agencies to go to workshops and training sessions to help other governments figure out how to do this type of thing.

So, I would suggest that our program for mitigating insider threat is probably one of the better ones around.

MR. RECKLEY: And Joe just went to the next bullet then, on this slide, that NAS was pointing out, in particular, that we look at insider threats and we do have programs for that and regulatory requirements for that in place.

MEMBER BLEY: I=m sure this is all true, but even in the safety area where, again, NRC is

preeminent in the world. When new things are developed, methodologies or programs, the staff often brings in an outside peer review team to comment.

And then you get a broad swath of things that aren=t just from within our own community here.

MR. RIVERS: Well, we actually do participate in activities where we engage with other agencies, other governments, industry. We participate in a number panel discussions and technical professional society meetings to try to figure out how we might do things better.

So, we do a lot of that. It may not be a full blown peer review study or something like that, but we do engage with our counterparts to try to understand how they might do it differently, that we can learn from that process.

MR. RECKLEY: And that=s just reinforced in this second bullet, that we=re not in isolation. We are interacting with other agencies, both law enforcement and home security here, as well as IAEA and NEA and other international bodies.

MEMBER BLEY: It=s a little related to what I suggested earlier. In the safety area, we=re good. But ever since the beginning of NRC=s

predecessor organization, there=s been an advisory committee or its predecessor kind of taking an extra look.

And I don=t -- there isn=t an equivalent kind of panel on the security side that I=m aware of. Is there?

MR. RIVERS: There=s no group like this that looks at our security program now.

MEMBER POWERS: Bill, in your previous slide, you noted operational experience. And I am moved to ask -- we used to have the AEOD, Analysis and Evaluation of Operational Data.

And, for a variety of reasons, that organization disappeared. The function is reputed to exist still. What=s your assessment of that? Was that a good thing to have?

Or are you still getting the needed information on operating experience? I mean, the AEOD itself used to publish fairly regular detailed topical reports on particular issues. We don=t see those anymore.

MR. RECKLEY: You don=t necessarily see the NUREGs in the same visibility that AEOD provided. I think the operational experience program still

remains very strong.

As a matter of fact, when we had the IAEA review mission, one of their comments positively was on operating experience. And now it=s run out of program offices, such as NRR has a strong one.

And ANSRs looking at the security-related operational experience. So I don=t know that it gets the visibility that it did --

MEMBER POWERS: It=s not getting the visibility to us, at least. It used to be your seat was regularly occupied by somebody from AEOD, and they provided this.

That=s something, Dennis, we need to think about.

MEMBER BLEY: Yes, well, my question related to that. For sure, it isn=t getting the same visibility to the public or to this committee. Is it getting the same visibility to the staff?

Because the staff used to have access to all of those reports from AEOD and used them routinely. And I don=t know if you -- it seems now, you pretty much have to decide to go over to OPE and ask for something rather than having it sitting there.

That=s an honest question. I don=t know

the answer to that at all.

MR. RECKLEY: I don=t think I=m going to -- it would just be a personal opinion. But it=s a good point. I=m not sure that even internally that it gets the --

MEMBER BLEY: I mean, personally, I=ve talked to people at OPE and they have a wealth of information.

MR. RECKLEY: Right.

MEMBER BLEY: And anytime I=m looking for something, we can go through them. But it=s not right there in front of you. And my question is, is the staff missing out on something because we don=t have that exposure?

It=s not a kind of question you have to answer here, but it=s one I want --

MR. RECKLEY: Well, I=ll tell you, just as a personal observation. The NRC has created a wealth of tools. And you can go onto our website and you can find a lot of useful stuff.

And how much the average staff knows where to find all of that stuff, I don=t know. But you can probably read into my statement that, not as well as we should.

Or that the tools are one level too deep in our IT system, or something. Because there=s a lot of useful stuff in terms of operational experience, knowledge management, that we=ve constructed that=s probably not as readily accessible as it should be.

MEMBER BLEY: And you brought up, even analysis tools are -- they=re not the same place, but --

MR. RECKLEY: Right, right.

MEMBER BLEY: But they are harder to find.

MEMBER POWERS: It does seem to be an area that might be useful to refresh our memories.

MEMBER BLEY: My memory going way back, is that AEOD happened because of this very thing. People said we really need to expose this kind of information.

And I kind of forget when it went away. It=s all there.

MEMBER POWERS: Well, I think Bill=s right. A dedicated individual can find whatever exists. Very seldom can you find things that don=t exist.

MEMBER SKILLMAN: They gave us a briefing about a year or year and a half ago. It=s been a long

time.

MR. RECKLEY: I can mention to Harold that it=s time for him to come back. So, again, the conclusion after all of that is that we don=t believe it=s necessary to redirect resources.

Again, that=s not to diminish any kind of -- that we don=t see value in independent assessments. But, as somebody mentioned earlier, we have a budget and we have to prioritize activities.

And is this where we think the best expenditure is going to be? And the conclusion is that it would not be. Now on to Recommendation 4.6, which is the validation of MELCOR.

We kind of discussed, within the SECY paper 16-0100, our thoughts on what we=ve done and what we use MELCOR for. Because you have to take both of those things into account.

Not only how accurate it is, but what you=re using the tool for. And so, we believe that when we use it for things, like we=ve done in the Fukushima response, not only the Spent Fuel Pool Study, but also, as you=re well aware, we used it for extensively in the other areas such as the study of Mark I and Mark II containments and other issues.

We believe that it has been validated for those uses and it=s sufficient for the purpose that we were using it, which was to make regulatory decisions, which are usually comparative.

What benefit might we get. So we=re running a base case, and then running a second case to see what the benefit or change would be. It has been benchmarked against the tests, as was mentioned, the Sandia tests. And the NUREG/CRs are there. Go ahead.

MR. ESMAILI: So, I knew there was an interest in end-to-end validation. And I was trying to understand what end-to-end validation means. So I actually brought some CDs of a number of MELCOR reports, including the ones that are here, plus some other things.

And these are on CDs, I have 15 copies, I can give it to you. You can take a look at it and see how this validation of MELCOR that we=ve been doing for the past 30 years.

So it=s nothing new to us. As information becomes available, as data becomes available, we do MELCOR validation. But, we consider MELCOR, there are two.

And where we have uncertainties, where

there are things that we don=t know, we rely on sensitivity calculations, et cetera, to bound the outcome of the phenomena.

MEMBER POWERS: This issue of validation and separate effects to -- the first comment, I guess, is a systems level code like this ever completely validated ever?

MR. ESMAILI: Against small scale experiments or against --

MEMBER POWERS: I don=t think you ever get it completely validated. I mean, even if you melted down reactors and calculated the results, somebody would say, well what about this other kind of reactor accident? I mean, you just never get there.

MR. ESMAILI: That=s true, because we still rely -- even our integral experiments are based on small scale experiments. A few assemblies, et cetera.

But, what we try to do is direct -- at least we have the correct physics. And if you have the correct physics and we do validation of these sub models, do we have heat above the fuel correct, or do we have oxidation, knowing that there are uncertainties of all of these phenomenon.

Whether it=s oxidation, kinetics, et cetera. And I think this is explained very well in the Academy=s report. And they refer to Professor Seagal=s book, that this is the state-of-the-art.

This is how we do things. And we do compare our code calculations with other code calculations. This is another level of trying to get a handle of what=s the scale up to the reactor or spent fuel pool applications.

MEMBER POWERS: Bill, to your point, on the use of the code -- I cannot think of any regulatory decision that hinged completely and 100 percent on a code calculation.

I mean, I just don=t. I mean there are a vast number of other factors that have to be borne in mind in making regulatory decisions other than -- the code informs your physical intuition on these things. It doesn=t make decisions for your, but --

MR. ESMAILI: And, in fact, this is -- it=s SECY-13-0030, the regulatory analysis. We did not do any MELCOR calculations for PWR. We relied on previous calculations that were often conservative.

But, as you said, looking at high density versus low density, the code provides a lot of

insights into what is important, what is not important.

Do we get a hydrogen explosion, don=t we get explosion? Do we get releases in both cases or not? So, these are the insights we get. And then, when we go and want to apply those, we always bias results towards higher releases, not knowing what the outcome of the accident is.

MEMBER RAY: Before you leave this point on your slide, you talk about the IRSN program. And can you elaborate what phenomena it will consider?

MR. ESMAILI: I think this -- I think they are looking at three separate phases. One is the whole pool. This is with water, natural circulation in the whole pool.

Second is, I think this was brought up at the partial drain down, so that you have a case where the fuel is uncovered. And do you get ingression of air into the assemblies?

The third phase, or the third aspect of the program, has to do with oxidation. In the presence of steam and air, they want to do more analysis so that they can implement that in their codes.

IRSN, they have their own severe code as you know, it=s AZTEC. And so, we are coordinating very, very closely with IRSN. We had crosswalks between MELCOR and other codes, like MAP.

And then we are having a crosswalk between MECLOR and AZTEC. So, we are learning, as part of our cooperative agreements, what are the models that are needed.

The issue of spray modeling came up. So, as we learn about this, these are the models that we are going to be implementing in our code. In addition to this, it=s not mentioned here, we know that the Japanese at the NRA are conducting several experiments similar to, in some respects, what DNPI is doing.

And they do have access to our code MELCOR. I know that they have been doing independent assessment of the code against the BWR five experiments.

And I think they are doing the same things when the data becomes available. So we are benefitting from their independent assessment of the code.

CHAIR REMPE: So, just to recap then, the IRS sends probably just PWRs --

MR. ESMAILI: This is just PWRs.

CHAIR REMPE: But the Japanese test will be doing some BWR testing?

MR. ESMAILI: They have, I think -- yes, I don=t know how far I want to go into that, because they are looking in BWRs. It=s probably 9 x 9. I don=t know if there=s going to be any 10 x 10.

But they are going to look at the phenomena. This is not public yet, what NRA is doing. But we are working very closely with -- well, not the details.

CHAIR REMPE: Okay.

MR. LEE: This is Richard Lee from Research. Within the DNPI program, the spray experiment being conducted by RSN on the PWR. And under the Japanese Regulatory Agency, they=re conducting spray experiments on BWR geometry.

So there=s some collaboration between those two organizations. And we have just been invited by RSN to join the DNPI. So, we are in discussion with them.

CHAIR REMPE: Okay.

MR. LEE: The program will last almost three more years.

CHAIR REMPE: Okay, thank you. Just out of curiosity, maybe the timing was the issue. But when went and briefed the Academy, did you mention these programs to them? I mean, with your recommendation, did --

MR. ESMAILI: I believe the IRS sent directly -- briefed the Academy on this DNPI project. Nicholas, I cannot pronounce the last name. But he presented the results and he presented the --

It=s in one of the presentations that was made to the Academy, it was by RSN under DNPI project.

CHAIR REMPE: Thank you.

MR. RECKLEY: So, going on to Recommendation 4.8, which was to do further evaluations of the dispersion of the fuel assemblies within the pool.

When we prepared SECY-1330, the Spent Fuel Pool Study and our recommendations to the Commission on expedited transfer, or to not proceed with expedited transfer.

The observation that comes out of the Spent Fuel Pool Study, as was mentioned in the NAS report and in the presentation of Dr. Shepherd, was the observation that when you do the fuel core offload

and you have the highest heat load, that=s the period of highest concern.

And so, the Commission, in its SRM for COMM SECY-1330, directed the staff to go back and take another look at the 60 days, in terms of achieving that dispersed pattern.

The staff looked at it and prepared, in response to that SECY-14-0136, which was in direct response to that. And Eric Bowman=s the author of that SECY paper, so he can weigh in as we go forward on the dispersion.

On the makeup systems -- again, the observation that those were first put in place after 9/11. They do include the ability to add water without going to the deck, by connecting two makeup systems or cooling systems associated with the spent fuel pool.

Or, adding water by going to the deck and running a hose. And then the nice thing about FLEX is that it gives you a couple different choices, based on what the actual conditions are that face the licensee.

In terms of the second bullet here, it recognizes that if you=re in a non-dispersed pattern, you should have the licensees, through the guidance,

have the capability to do that quicker.

Two hours if you=re a non-dispersed versus five hours if you=re in a dispersed pattern. I think those are the right numbers. Eric, if you could weigh in?

MR. BOWMAN: Yes, that=s right. This is Eric Bowman. As Bill mentioned, I=m the special advisor in the Japan Lessons-Learned Division. As far as the delivery of water to the spent fuel pools in the event of a need for water in the spent fuel pool, in the original set of spray strategies that was implemented after 9/11, it=s really a two-part strategy for the spray strategy.

There=s a local on-the-deck strategy, where the licensees would send personnel to the deck to run the fire hoses, or flexible hoses, and use a monitor nozzle to deliver the spray.

There was an additional portion of it, in the event that there was no access to the deck. It required licensees to have pre-planned strategies to spray from outside the building through breaches in the walls of the building.

Or, potentially use something like a crane or a ladder on a firetruck to raise a nozzle from

within the stairwell area and deliver water that way. That was in recognition of the same concerns that were expressed by some of the members of the committee.

If you have pre-installed or pre-positioned means of spraying water into the spent fuel pool, it would be vulnerable to the same event that caused the need to spray the water into the spent fuel pool.

So that=s what we had in place for the currently operating reactors. That=s in the guidance document in the I0612 revision 2. And the revision of that for new reactors in revision 3, we have also allowed new reactor designers to make use of installed seismically-qualified spray systems with stand pipes that are diverse in location.

So, for a hostile action-based event, there would be a lower likelihood that the entire system would be taken out. Now, the changes that were made for the mitigation strategies order for the FLEX program for the makeup capability, rather than the spray capability, we=ve also got provisions in the guidance that would require licensees to be capable of hooking up to the cooling system or some other means

to add water to the spent fuel pools without accessing the spent fuel pool decks.

MR. RECKLEY: So, after all of that, really the bottom line again is we need the balance, right? You can acknowledge that it would be better or not to have a full cool offload with it altogether, but there=s also operating considerations.

And we need to balance all of those things and, in the end, concluded that additional studies of either dispersing the fuel within the pool or going beyond what we=ve done for adding cooling would be unlikely to result in additional regulatory requirements.

So the Recommendation 4.10 was related to dry cask security. The rulemaking, the timing of this, ended up a little awkward in that the Committee was really recommending that we move along with that at about the same time we were writing the paper to recommend a deferral.

That reflects, really, a number of things that are changing. The decommissioning we=re making and the priority that=s being given to that. It=s just a little bit of internal prioritization that we need to do.

There=s been a lot of call for us to make progress on the decommissioning rulemaking. And so, it took a little bit away from this, although they=re actually related matters.

Some of the research activities that are going on, all of that lead to the staff recommending and the Commission agreeing and the staff requirements memorandum to defer the ISFSY security rulemaking for five years.

And so, it=s still on the books. We still plan to do it. But it=s being deferred. Now, whenever we do something like that, it=s also recognizing that we have things in place, right?

So there=s not necessarily a large void that that rulemaking was going to fill. And so, people are comfortable with its deferral.

MR. RIVERS: We have things in place, and we also have mechanisms that can allow us to put additional requirements in place, if they=re deemed appropriate, before rulemaking.

So, we=re not concerned that the ISFSYs are essentially not being adequately protected.

MR. RECKLEY: Moving on to 4.11, which was a risk assessment for expedited transfer. And we=ve

talked to the ACRS a few times on the matter of expedited transfer.

We do point out in SECY-16-0100 that there have been some risk assessments. 2161, the Spent Fuel Pool Study. Also NUREG 1864, which was a pilot PRA approach for dry casks.

We prepared COMM SECY-1330 to support a Commission decision. That paper with the deterministic analysis, the consequence analysis, the risk insights, was provided to the Commission.

They made their decision. One area that is brought up in the NAS paper and in other papers is the notion of integrating security along with those safety things.

The safety considerations, in particular, in the Spent Fuel Pool Study are the initiating event is assumed to be an earthquake. We point out in the paper, plant security is assessed.

It reads sometimes when you say that the study did not consider security, that somehow security is being forgotten. And that=s -- I don=t think that=s intention of it, but it can be read that way.

And we just like to feed back that we do consider security. It=s not fully-integrated with the

PRA, but it is considered elsewhere, such that in combination, the two things address safety and security, even though they=re not addressed in one integrated analysis in one PRA.

The two things are considered. And, in total, we look at the security requirements and the safety requirements, we think we have them both addressed, even though it=s not an integrated analysis.

So, again, every time we put in that this didn=t include security, and then it gets amplified in other places, I just don=t want it to be misread that somehow we=re forgetting or dismissing security.

It=s handled very extensively in another part of our regulatory program. One of the mentions within this part of the NAS report, and it was brought up by Dr. Rempe, was the other societal measures.

The consideration of psychological impacts or other societal measures. That is an area that=s been considered and discussed in terms of its inclusion on regulatory decisions and, in particular, decisions of environmental impact statements.

It was taken all the way up to the Supreme Court, and decided that it was too far attenuated from

the actual risk associated with an event and the release of radioactive materials to be required to be considered by the NRC.

And so, since that time, we didn=t do it before and this affirmed that we didn=t need to include it. Now, this Committee or another subcommittee has looked at other societal measures.

And we=re the first to acknowledge there=s different ways to do this from a staff perspective. We follow what the Commission directs us to do. And after Fukushima, we did look at whether we should do it differently.

And that was SECY-12-0110. The discussion at that time was largely on -- I=ll just use the Aland contamination@ was the terminology. And the Commission, again, came back and basically said to keep public health and safety as the primary measure.

And we are enhancing the guidance. And again, that=s matters that have been, and I imagine will be again, brought before the ACRS on how we do that, and the guidance on how we address different costs and different consequences within the regulatory analyses.

MEMBER BLEY: Remind me about the SRM on

that, because I don=t exactly remember. Do they just say to bring the one to the front burner and to the other in the background?

Or do they say don=t even think about the other one?

MR. RECKLEY: Fred can come up to the microphone if he wants to tell that. I don=t think they went as far as to say don=t do it. They did basically say don=t create another equivalent measure to public health and safety for land contamination.

MEMBER BLEY: Okay, that=s right, that helps me remember.

MR. RECKLEY: The staff=s was, we already addressed the cost of contamination, clean up, the impact on economies --

MEMBER BLEY: And the cost benefit.

MR. RECKLEY: -- within the cost benefit assessment. So, Fred, if you want to weigh in on any more?

MR. SCHOFER: Yes, Fed Schofer. Your recollections are correct. The reg analysis does address those factors. The key piece, though, is that radiological and economic -- or the consequences for land contamination don=t have the same standing,

specifically with regard to backfitting.

MR. RECKLEY: Yes, that=s the first test that you have to do, is that substantial safety improvement. And that doesn=t include the cost factor.

MEMBER RAY: Bill, we=re going to have a subcommittee meeting on the 7th of February on revision to reg analysis guidelines. I don=t know if this will come up then or not, but I just wanted to note that.

CHAIR REMPE: So, in some of the other papers that have been published, related to the Academy study, there was a concern expressed about whether the regulatory analysis had been appropriately performed because they couldn=t match what was done.

And they -- and I believe you responded back -- or someone from the NRC did -- about the shielding factors, and if the appropriate shielding factors were used. Can someone talk about that a little bit?

MR. RECKLEY: Keith can come up. While he=s coming up, the issue that was brought up is in our MAX analysis, we -- well, I=ll just let Keith --

MR. COMPTON: Sure, this is Keith Compton,

Office of Research. Yes, there was a question, and I think was in a paper by Professor Von Hipple, about the changes that -- trying to figure out what the appropriate level to use, in terms of cesium deposition to make a map, to try to match.

CHAIR REMPE: Yes.

MR. COMPTON: Because if he was using HYSPLIT, which is a dispersion calculation that doesn=t do exactly what MAX does. So he was trying to figure out how to get a consistent set of measures.

I would note that it kind of challenging to try to compare two different models. One of the issues is that, in MAX, when we do the does calculations, there is a factor --

There are factors that are used for shielding calculations for ground shine, so on and so forth. And the question is whether we should have -- what should one use for shielding factor in assessing dose.

So that was kind of the question. It should have went credited or not.

CHAIR REMPE: Yes.

MR. COMPTON: We kind of looked at it. We don=t have -- we do one-dose calculation, so we don=t

do a dose assessment for the long-term for protective action modeling and then a separate one to figure out what the actual dose would be.

There=s this issue of credit building shielding. Part of it -- there=s a couple of things to consider in that. One is that it=s very difficult to try to --

There=s a lot of uncertainties about what the actual interdiction levels would be. How would they be set after the event? So, how much would you credit the ability to have structural shielding if you were going to interdict an area or relocate people?

CHAIR REMPE: Yes.

MR. COMPTON: So, it=s not -- there=s the pad guidance, but we=re not -- it=s not clear as what the actual areas would be. The other one, probably the more significant, is that in our reg analysis process, MAX will give you an output of the interdicted area, which is going to give you costs.

But then it will also give you an estimate of the dose, the unmitigated dose. And we consider both of those things. So if you did a different shielding factor, or if you did a different way of calculating these levels, you might end up moving --

You might end up with more dose and less costs. Or if you move it the other way, less costs and more dose, you kind of go back and forth. We=re looking at both of those.

It=s not clear that that would change kind of an overall decision. And one of the things in our answer was that we look at a number of these things. And so, as far as actually trying to validate, I wouldn=t try to weigh in on exactly what the right number would be.

But, yes, we do use a shielding factor to do our interdicted area calculations.

CHAIR REMPE: And you feel it=s appropriate what you=re using?

MR. COMPTON: I think, yes. What we do is appropriate. Because, like I said, I believe that you would just kind of move from one issue to the other. If you did something that would project more interdicted area, you would end up with a lower population dose.

So, it=s important to look at all of the different measures.

CHAIR REMPE: Thank you.

MR. RECKLEY: So, again, the conclusion

with that one is that -- for the regulatory decisions that we needed to make, we thought we had the appropriate tools and were able to give the Commission the right information, and they ultimately made their decision.

And we don=t feel that we need to sponsor another study. So, with that, we=ve basically gone through the recommendations. I guess I would -- I don=t want to leave it with the impression that we just looked and dismissed.

In many more cases, we looked and we thought we had things going on that were closely related, and we will continue those. But not necessarily -- well, not in any case, are we, as a direct result, going to spend more money or accelerate schedules.

But in many cases, we already had things going on and we=ll continue those. So, questions?

CHAIR REMPE: Since there are no more questions for the other members, I=d like to thank all of you, as well as the folks in the audience for coming -- the staff and the audience, to come and answer our questions.

Well, first of all, let=s ask if there=s

anyone in the room who wants to make any comments?

MR. SHEPHERD: So, this is Joe Shepherd. So I first of all would like to thank the staff for their very thorough and careful reading of the report. It=s pretty dense and there=s a lot there and, obviously, you took time do that and consider it.

And listening to your responses, I just have a few things that I would like to indicate. One of the things is about 4.1B. And that was this discussion about the security risk assessment.

You had indicated on your slide, I think it=s slide 9, that the recommendation that we were making in 2016 -- no, that=s not the slide, so I want 4.1B.

I apologize, I have the wrong slide. So, the third bullet says, ASimilar findings and conclusions the NAS 2016 report.@ I=m sorry, but that=s not the case.

In 2006, they said that it was not possible to do probabilistic risk assessment on security. Whereas in 2016, we said that=s something that we have increasing capability and should try to do.

I=d just like to point out that, because

this in fact was a tremendous point of contention in the Committee in a lot of discussions, I just wanted to clarify that we took a big leap to get there, and I don=t want to leave that aside.

Regarding now slide 9 -- now I do want to talk about slide 9. So, here, I=d like to point out that this is not exactly what we stated as our recommendation.

What we had said, if the independent assessment that was recommended in 2006 shouldn=t include an examination, the effectiveness of the insight.

So, it=s really just saying, something a little bit short of -- we didn=t say Ashould obtain@, that was not part of our recommendation. We were very careful to not give you direction of that sort, recognizing the limitations of our authority.

And then, I would like to say that the motivation for us, including this, and you had extensive discussion -- but, really, our motivation was just to say, how do you know how well the insider threat mitigation program was working?

And to know that really requires some sort of assessment. That was really what we were saying.

Finally, I=d like to say something about the MELCOR. MELCOR is a very complex tool.

I actually have looked at the reports that Hussein referenced, in some detail, to understand the models. I would like to point out that it does not model all physical phenomenon.

There is, in fact, one special case of physical phenomena which is buoyancy in large open areas that it cannot treat because it does not have the bonafide momentum equation.

And everyone that=s familiar with the code will recognize that. And what that means is it=s -- you have to treat any large volume as simply a lumped volume, and you cannot include stratification and circulation connections, although you can do buoyancy within the fuel.

The other thing is about the validation. The only validation that I know of, relative to the spent fuel heat oven combustion issue is the validation score of air experiments that were done at Sandia. That=s it.

There are other aspects of that for partially-drained fuels and sprays have not been validated, to my knowledge.

CHAIR REMPE: And these are just comments, so there won=t be a response back. Anyone else in the room? So is there anyone on the line that wants to provide a comment?

And, not seeing any, let=s start going around the room and, I guess, let=s start with Pete.

MEMBER RICCARDELLA: As I read it, the Phase II report is addressing lessons learned from Fukushima, with a focus on spent fuel pool safety. But, as Dana said, with the spent fuel pool, you=re looking at days to respond versus in a reactor and the things addressed in a reactor, we=re talking hours or less to respond.

The industry is spending billions of dollars on FLEX programs to address Fukushima, which includes -- the objectives are to maintain core cooling, containment cooling, and spent fuel core.

That=s one of the things being addressed. And, among the actions being taken are the requirement to install reliable spent fuel pool monitoring instrumentation and FLEX equipment to re-flood the pools, if needed.

And I just don=t see, in my mind, the need for additional programs to address what appear to be

low priority aspects of the Fukushima accident.

CHAIR REMPE: Thank you. Charlie?

MEMBER BROWN: I have no other comments.

CHAIR REMPE: Walt?

MEMBER KIRCHNER: No comments. Thank you all.

CHAIR REMPE: Jose?

MEMBER MARCH-LEUBA: No comment.

CHAIR REMPE: John?

MEMBER STETKAR: Nothing more, except to -- I do support the recommendations from NAS to start looking more carefully at the nexus between security and safety.

I think we have tools to be able to start doing that. And, as Dennis mentioned, if you don=t start, there=s always a lot of reasons why you can=t.

CHAIR REMPE: Okay. Dennis?

MEMBER BLEY: I agree with John. Nothing more to add. I know you=ll thank them, but I=d really like to thank everyone for the presentations and, especially, Joe Shepherd for coming all the way here to talk with us. I appreciate it.

CHAIR REMPE: Yes. Do you want to make a comment, since you=re -- okay, Dana.

MEMBER POWERS: First of all, I appreciate Mr. Riccardella=s comments, and I certainly echo those. And I also agree with Dennis and John that we will not make progress on the security safety nexus without trying.

But I will comment that already, to my mind, PRA has gotten so involuted and so complicated, sophisticated, that it=s becoming inscrutable to the non-specialist.

And if we continue that by also integrating in security, we=re liable to get to a point that it will be very difficult to scrutinize either the PRA or the security status of things.

The softer coordination that was described to us, I think, should not be underestimated as an effective way to deal with the combination of security and safety in the absence of some miraculous stride in our analysis technology.

CHAIR REMPE: Dick?

MEMBER SKILLMAN: I would just thank Dr. Shepherd and Mr. Crowley and Bill and the staff. Thank you.

CHAIR REMPE: Okay. Harold?

MEMBER RAY: No, I have nothing to add,

other than to again say we=ve got this subcommittee meeting coming up on February 7th that I think will be linked in some limited way to what we talked about here today.

CHAIR REMPE: Margaret?

MEMBER CHU: I want to thank everybody for giving the presentations. I just want to make one comment. I agree with the Academy=s recommendation of doing a risk assessment of a spent nuclear fuel.

And I know NRC has done a lot of things for the spent fuel science and all that, but I just don=t know whether you have done a very comprehensive and rigorous assessment of safety of spent fuel.

I think, given the new age we are in, and then I=d really hate to see something happen down the road, and then we say oops we hadn=t thought of that thing and we wish we had. And that=s just my personal comment.

CHAIR REMPE: Matt?

MEMBER SUNSERI: I=d like to also extend my thanks to Dr. Shepherd and the staff for the remarks made today. Coming recently out of the industry, I have some background in the protection of spent fuel pools and with the security requirements of

the plants.

And a lot of the NAS report recommendations along those lines resonate with me. And I think the industry and the regulator have both done, either as a result of the lesson learned from Fukushima or through self-awareness or whatever, it=s taken a lot of effort to improve our ability to keep the fuel and the spent fuel pools protected, covered.

Diverse means to get water in there under diverse scenarios, if you will. And I personally feel pretty confident that they=re well protected, in addition to the security aspects as well.

I know, as mentioned, we ran all kinds of security drills, constantly staying up with the threat to try to stay at least parallel with the ingenuity of the people that might do harm to the plants.

So, try to get in front of them as much as we can, so -- like I said, a lot of those recommendations come out of the report resonate with me, and I think probably with the industry and the regulator because there=s so much action going on in parallel.

So, thanks for all of the comments and I appreciate it.

CHAIR REMPE: And Ron?

MEMBER BALLINGER: No further comment.

CHAIR REMPE: Okay. Well, as Dennis indicated, I do want to thank again the staff, as well as Joe and Kevin, for coming. This is an information briefing, and it=s to help educate us and understand more of the details in your report, as we do our work.

And it helps to understand some nuances about the staff response. And so, I found it beneficial, as a member. And that=s why I requested, and I=m glad that we did have, this meeting. And with that, let=s adjourn.

(Whereupon, the above-entitled matter went off the record at 11:45 a.m.)

LESSONS LEARNED from the Fukushima Nuclear Accident for Improving Safety and Security of U.S. Nuclear Plants: Phase 2

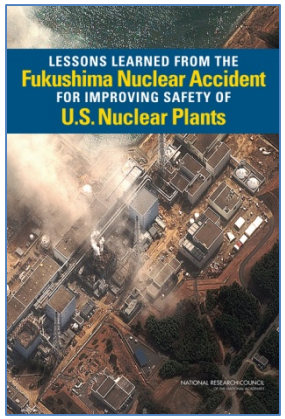
Briefing to the Advisory Committee on Reactor Safeguards

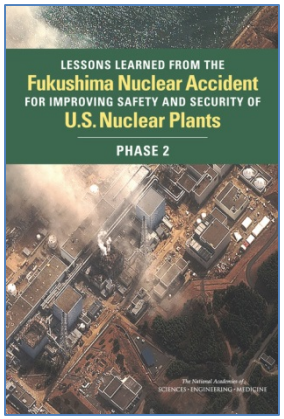
November 30, 2016

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

Background

- Requested by Congress in conference report from the Consolidated Appropriations Act of 2012 (P.L. 112-74)
- Sponsored by the U.S. Nuclear Regulatory Commission (USNRC)
- Study was carried out by in two phases:
  - Phase 1: Completed July 2014
  - Phase 2: Completed May 2016





This briefing focuses on the Phase 2 report

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Abbreviated Statement of Task

1. Lessons learned from the accident for improving safety of spent fuel storage (Chapter 2)
2. Security-related lessons learned from the Fukushima Daiichi accident for improving nuclear plant systems, operations, and regulations (Chapter 3)
3. Reevaluation of the findings and recommendations from previous NAS reports on spent fuel storage safety and security (Chapters 4-7)

Report Findings and Recommendations

- Phase 2 report contains
  - **14 Findings**
  - **7 Recommendations**
- Recommendations are not prioritized

Findings and Recommendations

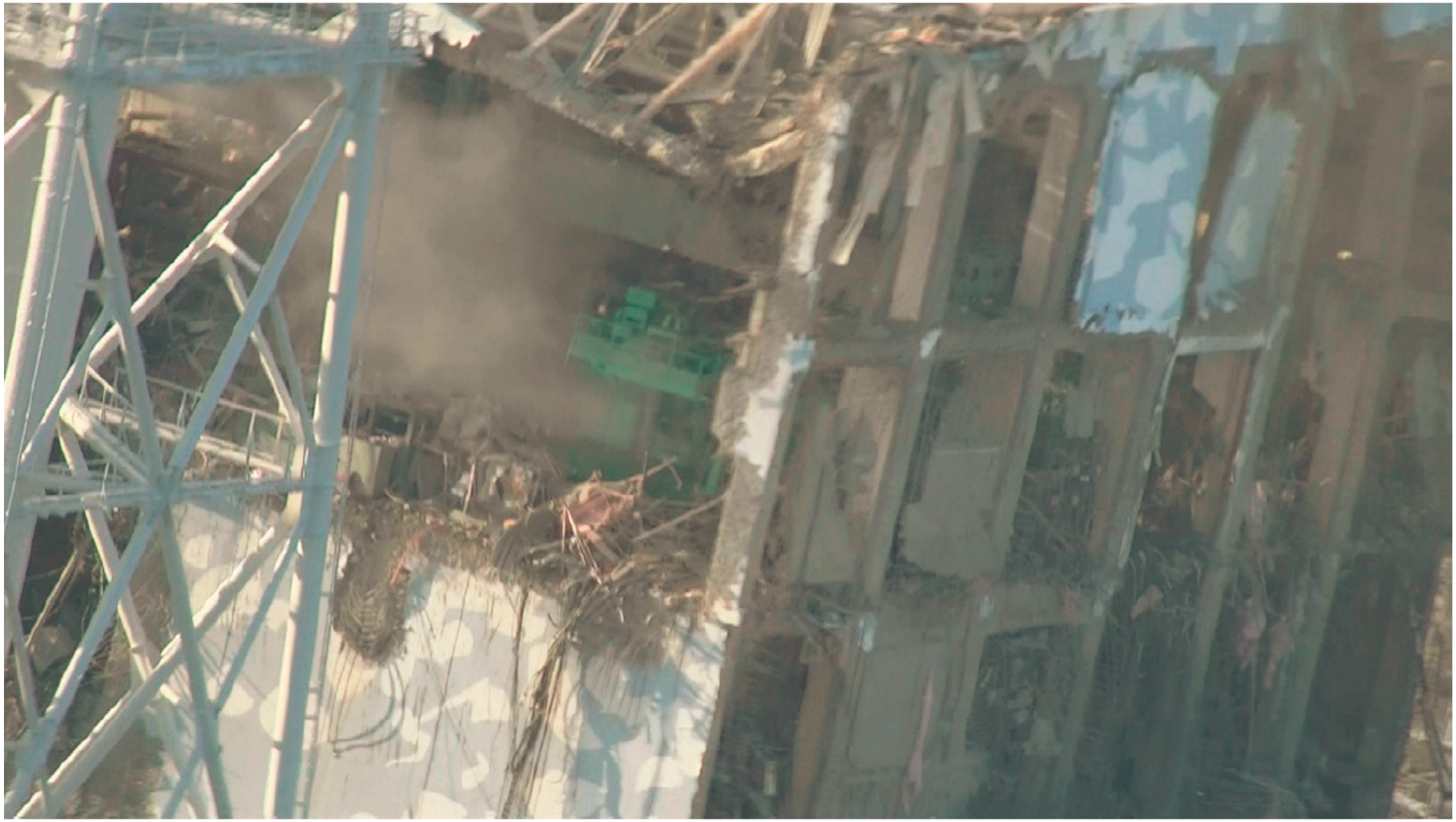
Lessons Learned for Spent Fuel Safety (Chapter 2)

FINDING 2.1:

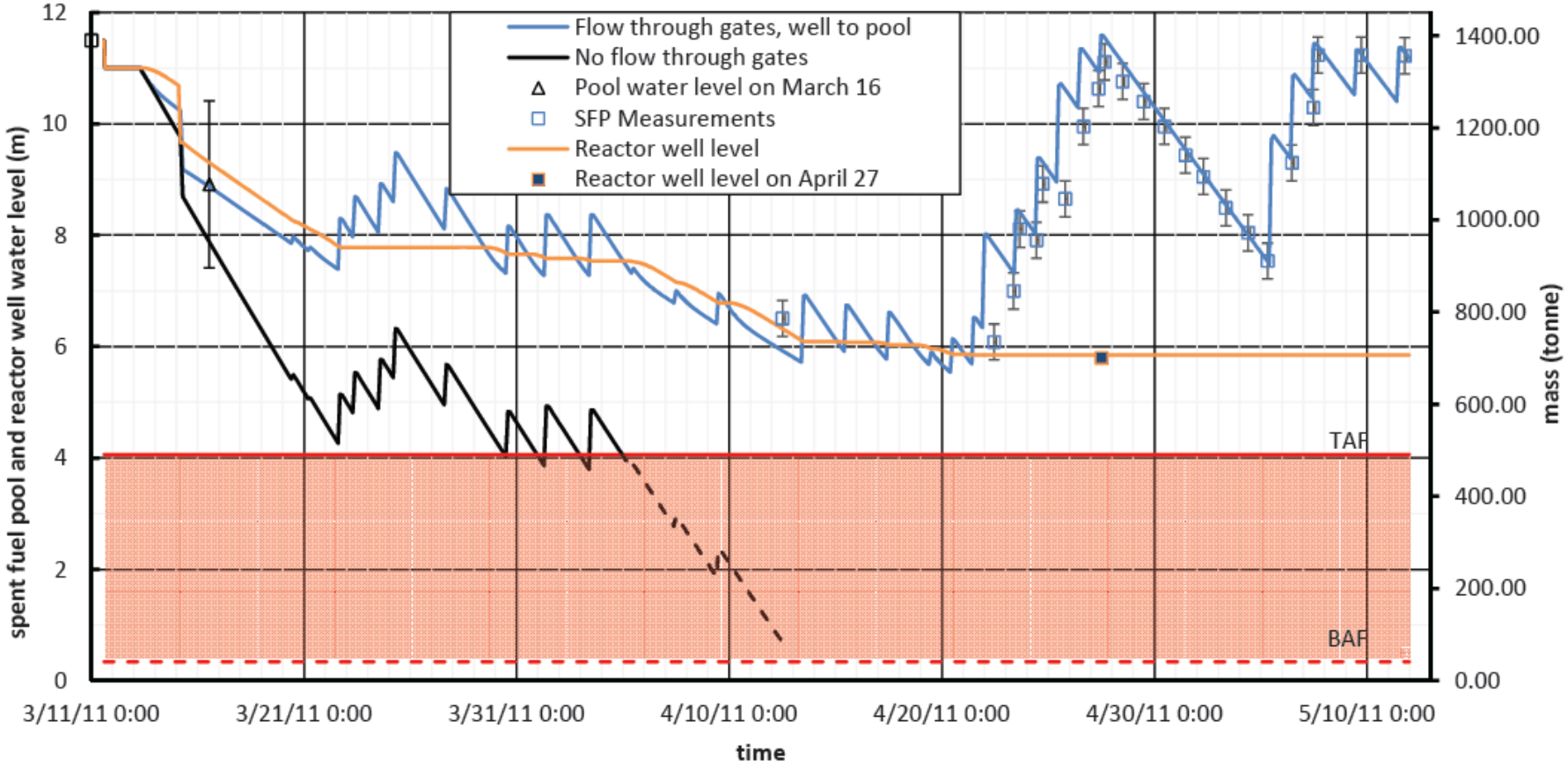
The spent fuel storage facilities (pools and dry casks) at the Fukushima Daiichi plant maintained their containment functions during and after the March 11, 2011, earthquake and tsunami. However, explosions in the Unit 1, 3, and 4 reactor buildings damaged spent fuel handling facilities and equipment... The lack of reliable real-time information about the pools created substantial difficulties in responding to the accident and led to increased public anxiety. Nevertheless, plant personnel were able to improvise and provide needed cooling to avoid pool uncovery and potential radiological consequences. The leakage of water into the Unit 4 pool from the reactor well/dryer-separator pit was a key factor for determining its water level and may have prevented fuel uncovery before plant personnel were able to add water.

Fukushima Daiichi before March 11, 2011

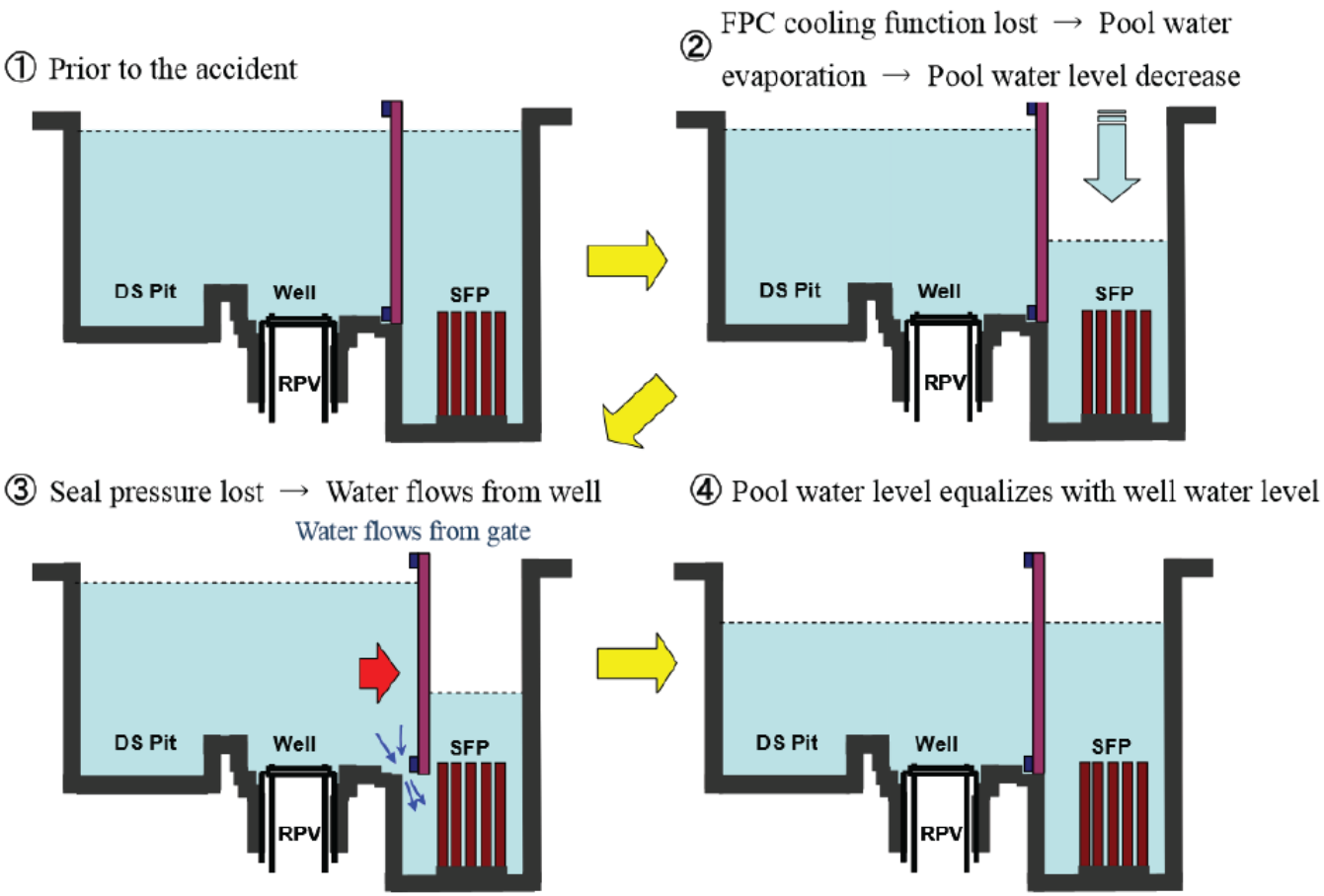
Unit 4 – March 16, 2011



Unit 4 Spent Fuel Pool Water Level Analysis

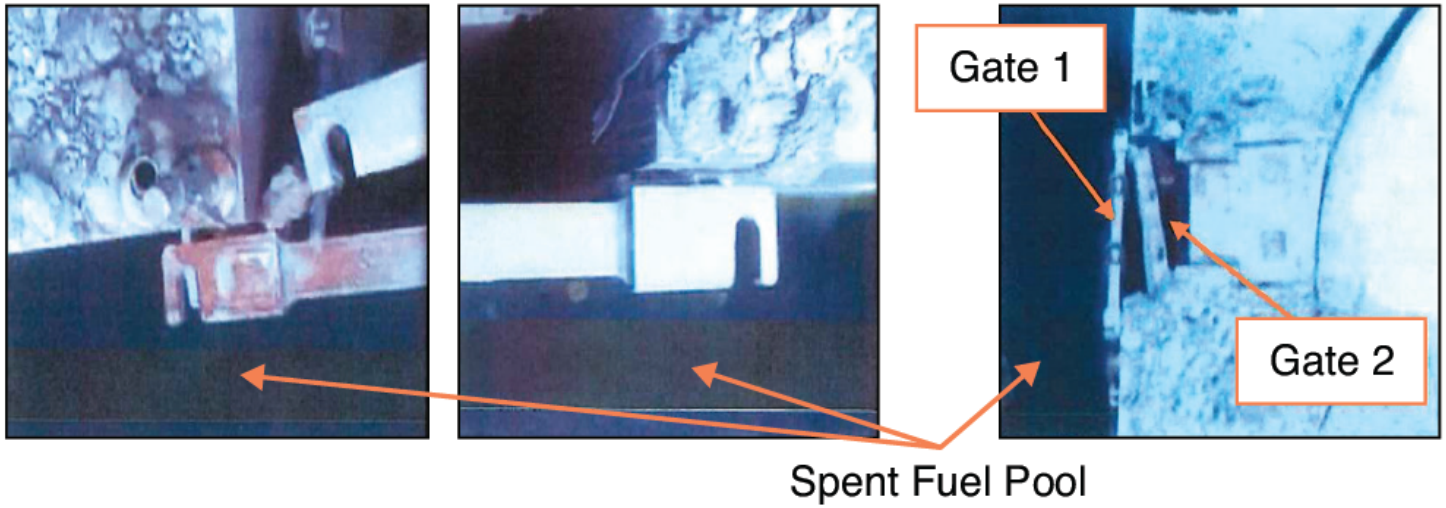


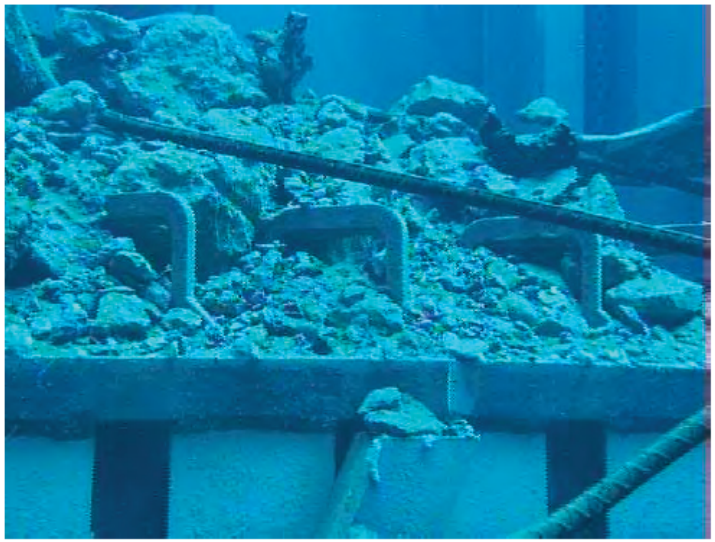
Key Role of Gate Leakage and Outage Condition

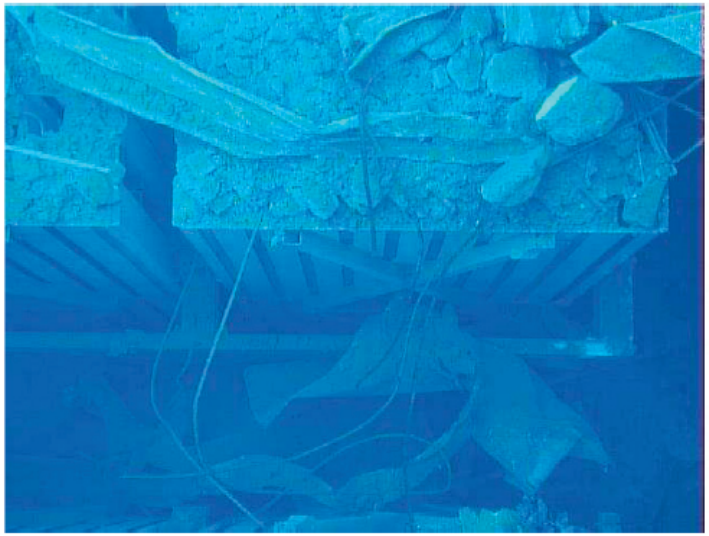


Leakage through the gate seals was essential for keeping the fuel in the Unit 4 pool covered with water. Had there been no water in the reactor well, there could well have been severe damage to the stored fuel and substantial releases of radioactive material to the environment.

Damage to Gates and Debris in Unit 3 Pool







Lessons Learned for Spent Fuel Safety

- It can be difficult to deal with loss-of-cooling events in spent fuel pools during severe accidents/wide area emergencies, especially when pool instrumentation is unavailable and pool decks are inaccessible.
- The situation in the Unit 4 pool highlights the potential for fuel uncovery during extended loss-of-coolant events in reactors undergoing maintenance.
- Fuel uncovery in the Unit 4 pool was arguably prevented by the leakage of water from the reactor well/dryer-separator pit before plant personnel were able to add water to the pool.

The events in the Unit 4 pool should serve as a wake-up call to nuclear plant operators and regulators about the critical importance of having robust and redundant means to measure, maintain, and, when necessary, restore pool cooling.

Recommendation 2.1

The U.S. nuclear industry and its regulator should give additional attention to improving the ability of plant operators to measure real-time conditions in spent fuel pools and maintain adequate cooling of stored spent fuel during severe accidents and terrorist attacks. These improvements should go beyond the current post-Fukushima response to include hardened and redundant

(1) physical surveillance systems (e.g., cameras),

(2) radiation monitors,

(3) pool temperature monitors,

(4) pool water-level monitors, and

(5) means to deliver pool makeup water or sprays even when physical access to the pools is limited by facility damage or high radiation levels.

Lessons Learned for Security (Chapter 3)

Finding 3.1

Extreme external events and severe accidents such as occurred at the Fukushima Daiichi plant can cause widespread and long-lasting disruptions to security infrastructure, systems, and staffing at nuclear plants. Such disruptions can create opportunities for malevolent acts and increase the susceptibility of critical plant systems to such acts.

Recommendation 3.1

Nuclear plant operators and their regulators should upgrade and/or protect nuclear plant security infrastructure and systems and train security personnel to cope with extreme external events and severe accidents. Such upgrades should include

- Independent, redundant, and protected power sources dedicated to plant security systems that will continue to function independently if safety systems are damaged;
- Diverse and flexible approaches for coping with and reconstituting plant security infrastructure, systems, and staffing during and following extreme external events and severe accidents; and
- Training of security personnel on the use of these approaches.

The U.S. nuclear industry should consider expanding its Diverse and Flexible Coping Strategies (FLEX) capability to address this recommendation. The USNRC should support industry's efforts by providing guidance on approaches and by overseeing independent review by technical peers (i.e., peer review).

Re-evaluation of Previous Academies Reports (Chapters 4-7)

Previous Academies Reports: Safety and Security of Commercial Spent Nuclear Fuel Storage

- NRC (2004): classified report
- NRC (2006): public report

- Issues Examined:
  - Terrorist attacks on or theft of spent fuel
  - Safety and security of pool storage
  - Safety and security of dry cask storage and comparison with pool storage
  - Implementation issues

Evaluation of US NRC Response to Previous Reports

The U.S. Nuclear Regulatory Commission has implemented most of the recommendations from previous Academies reports on spent fuel safety and security.

Two recommendations were not implemented. See Findings 4.3 and 4.7.

Carry out an independent examination of surveillance and security measures for protecting stored spent fuel (4.3)

Analyze the vulnerabilities of spent fuel pools to specific terrorist attack scenarios (4.7)

Terrorist Attacks on or Theft of Spent Fuel

FINDING 4.1

The understanding of security risks at nuclear power plants and spent fuel storage facilities can be improved through risk assessment. Event trees and other representational formalisms can be used to systematically explore terrorist attack scenarios, responses, and potential consequences. Expert elicitation can be used to rank scenarios; develop likelihood estimates; and characterize adaptive adversary responses to various preventive, protective, or deterrence actions. The identification of scenarios may be incomplete, and the estimates developed through expert elicitation are subjective and can have large uncertainties. Nevertheless, risk assessment methods that focus on the risk triplet—scenarios, likelihoods, and consequences—can contribute useful security insights.

RECOMMENDATION 4.1A

The U.S. nuclear industry and the U.S. Nuclear Regulatory Commission should strengthen their capabilities for identifying, evaluating, and managing the risks from terrorist attacks. Particular attention is needed to broaden scenario identification, including asymmetric attacks; account for the adaptive nature of adversaries; account for the performance of plant security personnel in responding to the identified scenarios; estimate the potential onsite and offsite consequences of attack scenarios, including radioactive releases and psychological impacts; and develop strategies for countering the identified threats.

RECOMMENDATION 4.1B

The U.S. Nuclear Regulatory Commission should sponsor a spent fuel storage (wet and dry storage) security risk assessment for U.S. nuclear plants. The primary objectives of this assessment should be to (1) develop and exercise the appropriate methodologies for characterizing risk and estimating uncertainties, and (2) explore the benefits of risk assessment for enhancing security at U.S. nuclear plants. This assessment should be subjected to independent review by technical peers (i.e., peer review) as part of the development process.

FINDING 4.3

The U.S. Nuclear Regulatory Commission has not carried out an independent examination of surveillance and security measures for protecting stored spent fuel that was recommended by NRC (2006).

RECOMMENDATION 4.3

The independent examination of surveillance and security measures for protecting stored spent fuel recommended by NRC (2006) should include an examination of the effectiveness of the U.S. Nuclear Regulatory Commission's programs for mitigating insider threats.

Safety and Security of Pool Storage

FINDING 4.5

Technical analyses undertaken by the U.S. Nuclear Regulatory Commission and Sandia National Laboratories after 2004 confirm that reconfiguring spent fuel in pools can be an effective strategy for reducing the likelihood of fuel damage and zirconium cladding fires following loss-of-pool-coolant events. However, reconfiguring spent fuel in pools does not eliminate the risks of zirconium cladding fires, particularly during certain periods following reactor shutdowns or for certain types of pool drainage conditions. These technical studies also illustrate the importance of maintaining water coolant levels in spent fuel pools so that fuel assemblies do not become uncovered.

FINDING 4.6 (abbreviated)

Additional analyses and physical experiments carried out by the U.S. Nuclear Regulatory Commission and Sandia National Laboratories since NRC (2006) was completed have substantially improved the state of knowledge of BWR and PWR spent fuel behavior following partial or complete loss of pool water.

RECOMMENDATION 4.6 (abbreviated)

The U.S. Nuclear Regulatory Commission should (1) sponsor an end-to-end validation of the MELCOR code for use in modeling coolant loss in spent fuel pools, and (2) validate key submodels in the code.

FINDING 4.7 (abbreviated)

The U.S. Nuclear Regulatory Commission has not analyzed the vulnerabilities of spent fuel pools to the specific terrorist attack scenarios identified in Recommendation 3E-1 in NRC (2004).

FINDING 4.8 (abbreviated)

The U.S. Nuclear Regulatory Commission and the U.S. nuclear industry have made good progress in implementing actions to address Recommendation 3E-2 in NRC (2006).

Recommendation (2006) 3E-2: Take prompt and effective measures to reduce the consequences of loss-of-pool coolant events in spent fuel pools:

- Reconfigure fuel in pools to distribute decay heat loads
- Make provision for water spray systems to cool the fuel even if the pool or overlying building were damaged

RECOMMENDATION 4.8

The U.S. Nuclear Regulatory Commission should take the following actions to more fully implement Recommendation 3E-2 in NRC (2006):

- Reexamine the need for the 60-day limit for fuel dispersion and reduce the allowable time if feasible.
- Reexamine and, if needed, redesign the water makeup and spray systems and strategies to ensure that they can be implemented when physical access to pools is hindered or the site becomes inaccessible.

Safety and Security of Dry Cask Storage and Comparison with Pool Storage

FINDING 4.10

The U.S. Nuclear Regulatory Commission is incorporating the results of its dry cask vulnerability analyses into its regulations through rulemaking. The rulemaking was still in progress when the present study was being completed; consequently, the committee was unable to evaluate its technical soundness and completeness.

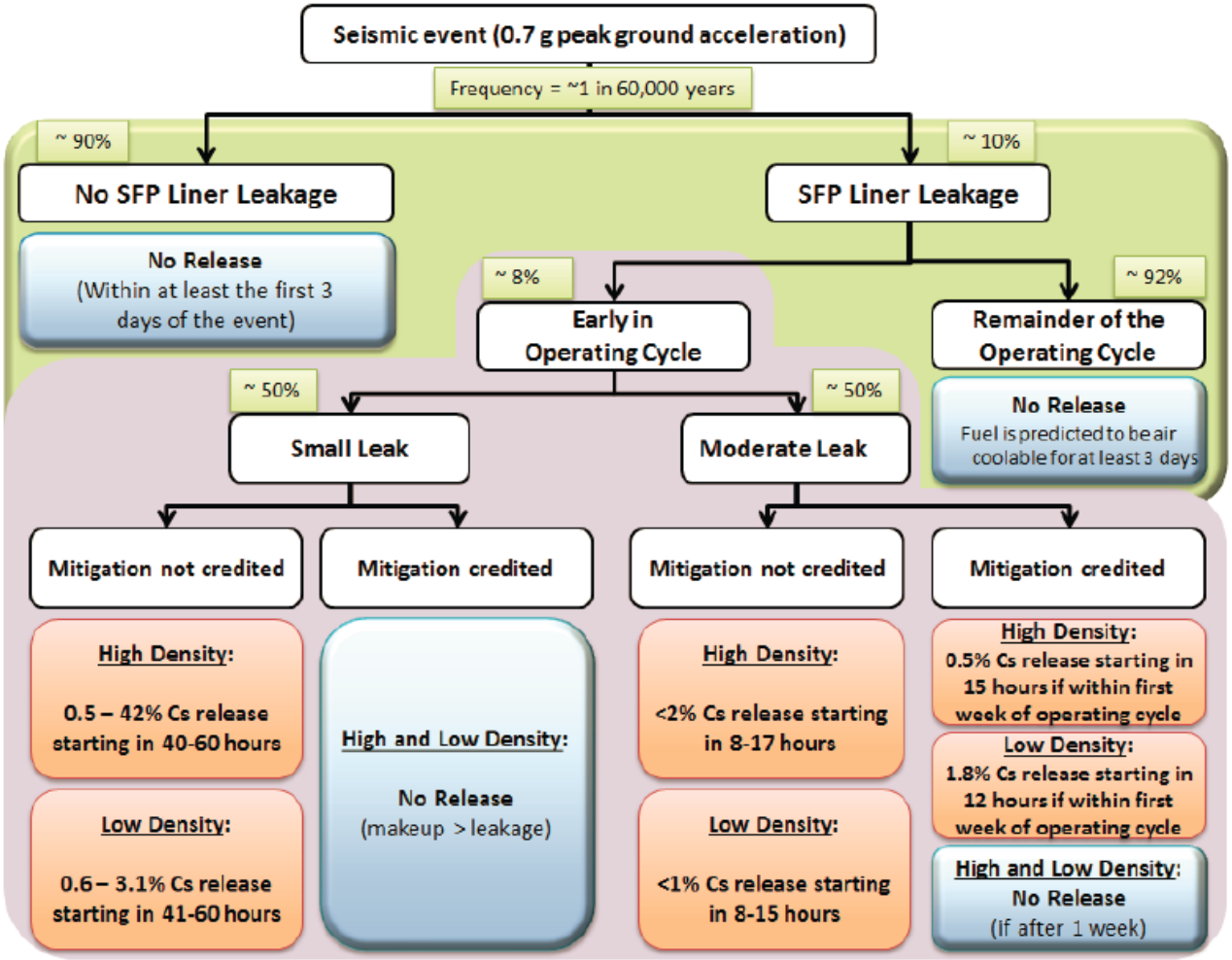
RECOMMENDATION 4.10

The U.S. Nuclear Regulatory Commission should give high priority to completing its analyses on dry cask storage vulnerabilities and rulemaking.

FINDING 4.11

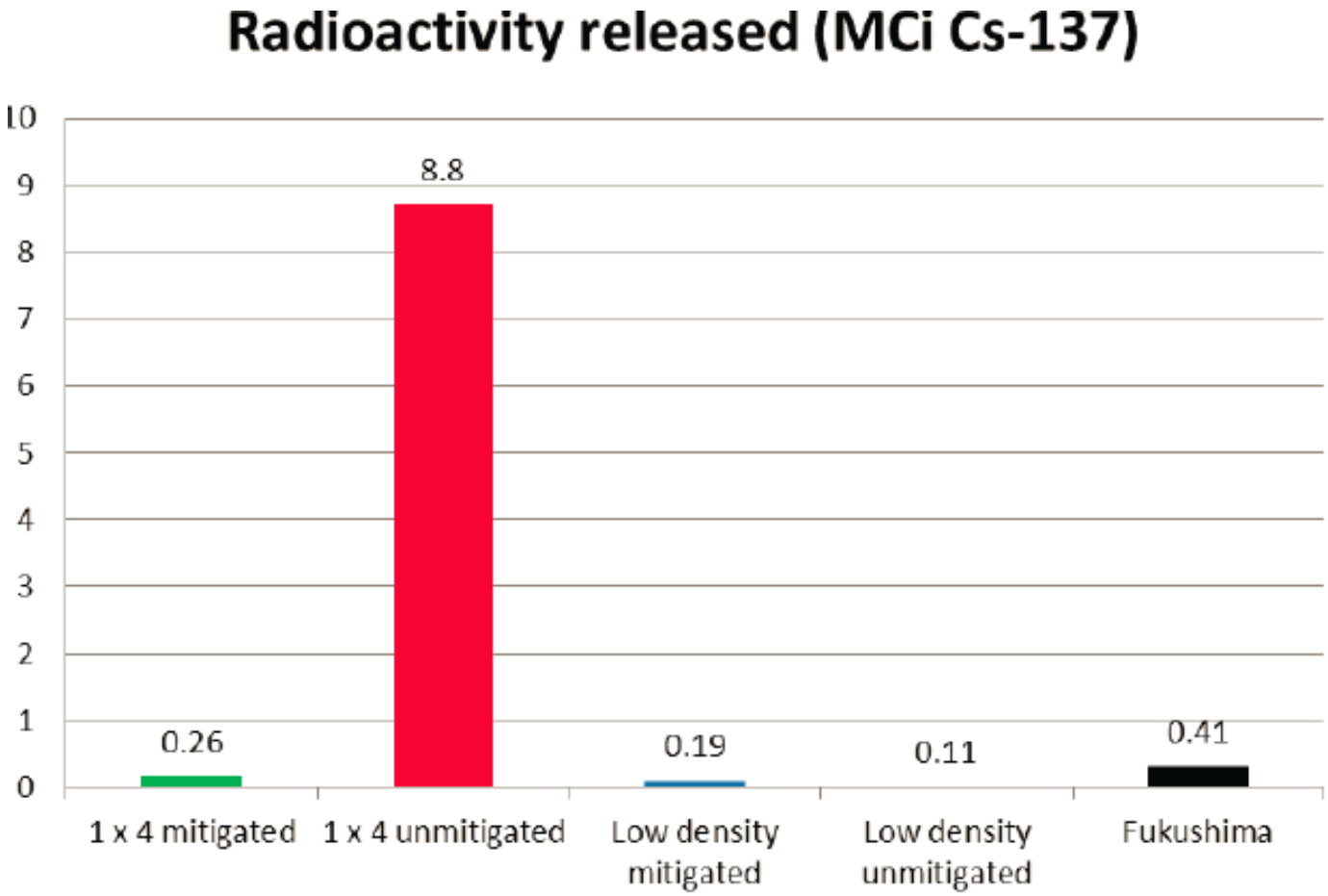
The U.S. Nuclear Regulatory Commission has completed a technical analysis of spent fuel pool accident consequences to inform a regulatory decision on expedited transfer of spent fuel from pool to dry cask storage. The analysis was carried out in accordance with prescribed U.S. Nuclear Regulatory Commission regulatory guidance and provides valuable technical information about the impacts of various accident scenarios on spent fuel storage in pools. However, the analysis did not consider spent fuel storage sabotage risks, dry cask storage risks, or certain health consequences that would likely result from a severe nuclear accident. The analysis also used simplifying bounding assumptions that make it technically difficult to assign confidence intervals to the consequence estimates or make valid risk comparisons. **A risk assessment that evaluates the three questions of the risk triplet and that accounts for uncertainties in both probability and consequence estimates is needed to address Finding 4E in NRC (2006) to determine whether "earlier movements of spent fuel from pools into dry cask storage would be prudent to reduce the potential consequences of terrorist attacks on pools at some commercial nuclear plants."**

Spent Fuel Pool Study Rationale



Note: The low-density pool has about 1/3 of Cs-137 inventory compared to high-density pool. Early in the operating cycle refers to early time after shutdown.

Spent Fuel Pool Study



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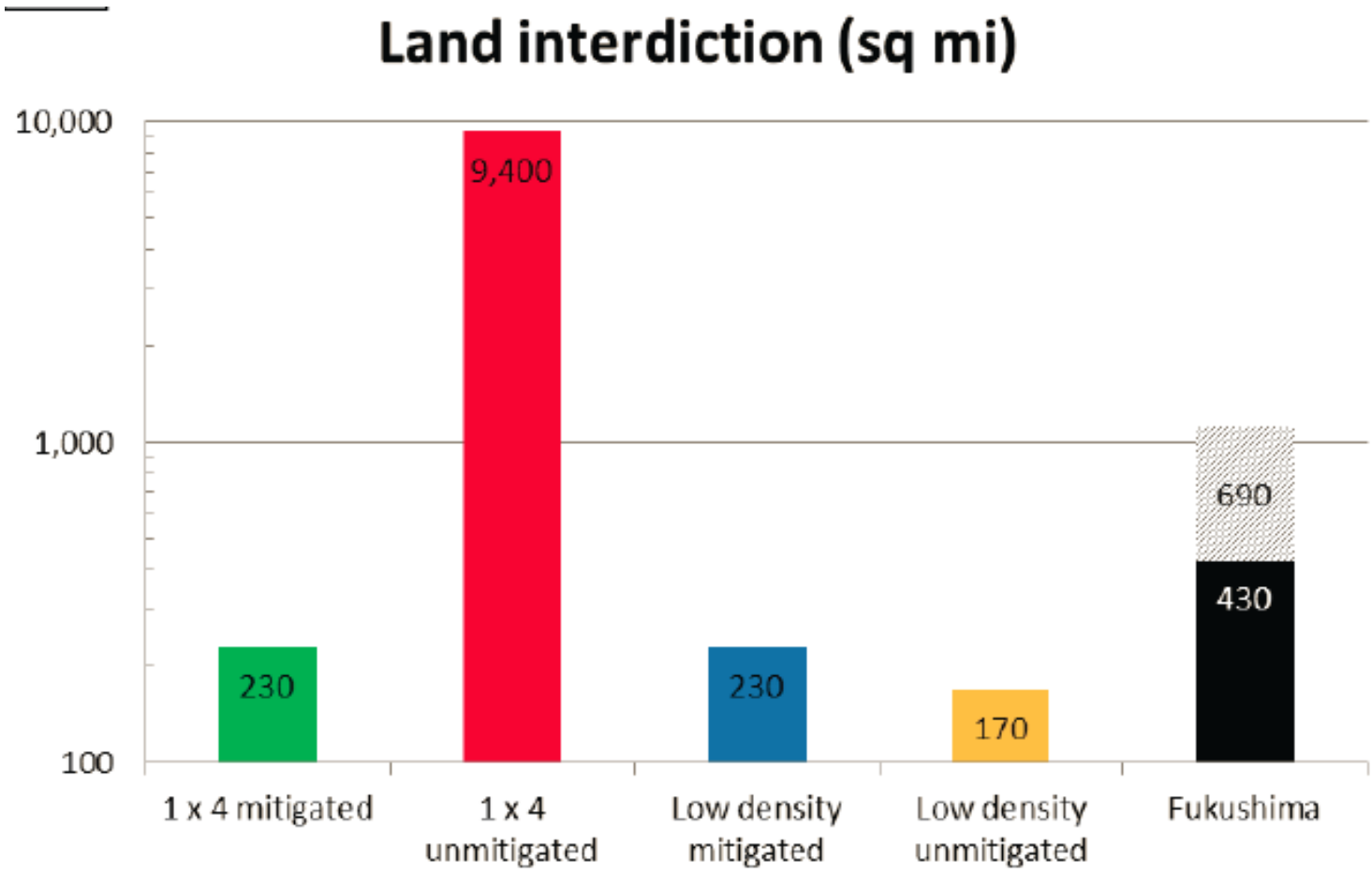
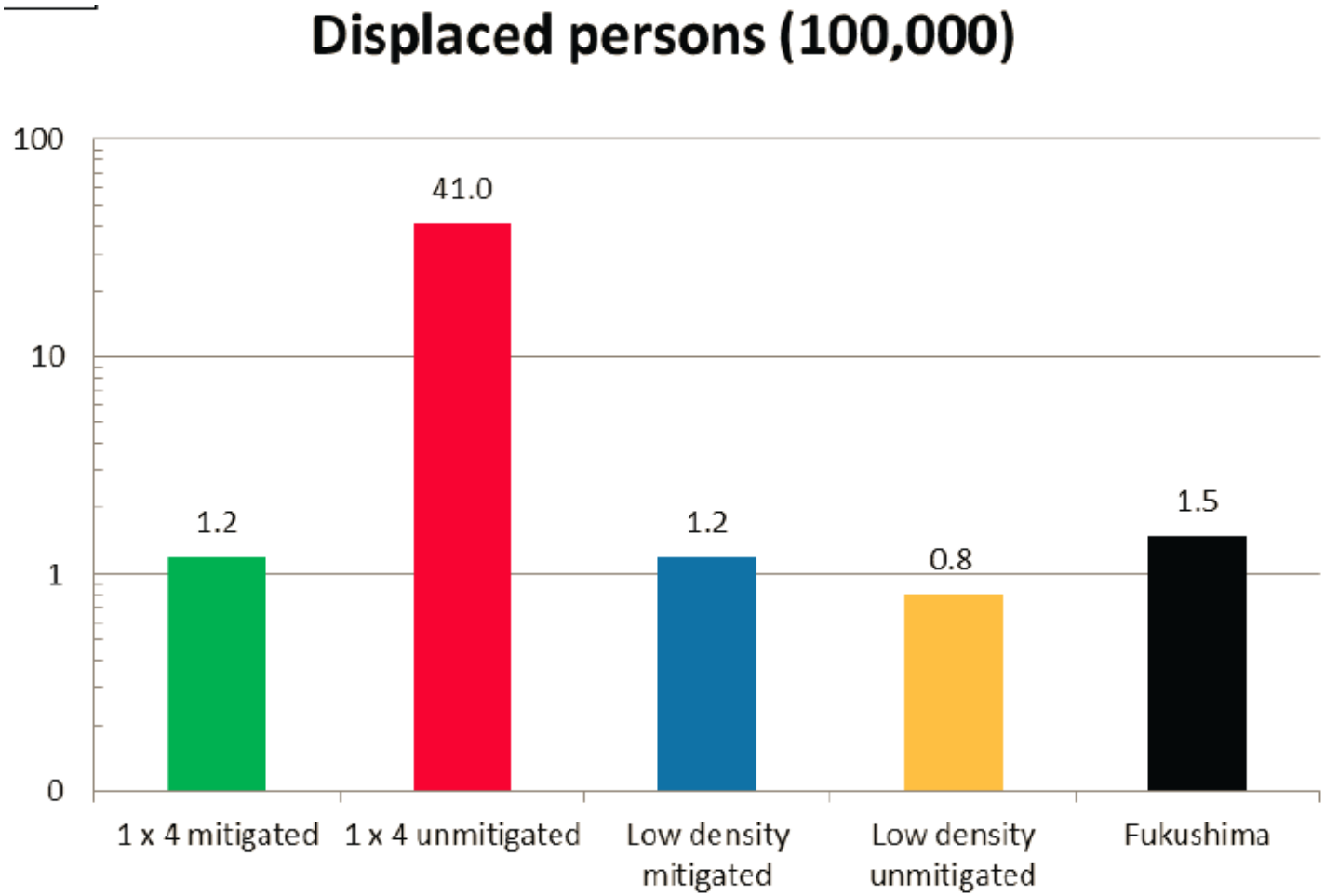


Spent Fuel Pool Study



Transfer of Spent Fuel from Pools to Dry Casks

The U.S. Nuclear Regulatory Commission completed a technical analyses of spent fuel pool accident consequences to inform a regulatory decision on expedited transfer of spent fuel from pool to dry cask storage.

- These analyses are valuable technical contributions to understanding the consequences of spent fuel pool accidents.
- However, they are of limited use for assessing spent fuel storage risks because they did not consider spent fuel storage sabotage risks, dry cask storage risks, or certain health consequences that would likely result from a severe nuclear accident, and they used simplifying bounding assumptions that make it technically difficult to assign confidence intervals to the consequence estimates or make valid risk comparisons.

RECOMMENDATION 4.11

The U.S. Nuclear Regulatory Commission should perform a spent fuel storage risk assessment to elucidate the risks and potential benefits of expedited transfer of spent fuel from pools to dry casks. This risk assessment should address accident and sabotage risks for both pool and dry storage. The sabotage risks should be assessed using the methodology developed in response to the present committee's Recommendation 4.1B.

Implementation Issues

FINDING 4.12 (Abbreviated)

The U.S. Nuclear Regulatory Commission has made a commendable effort to improve the sharing of pertinent information on vulnerability and consequence analyses of spent fuel storage with nuclear power plant operators and dry cask storage system vendors.

Summary of New Recommendations (Ch 4-7)

- Strengthen capabilities for identifying, evaluating, and managing the risks from terrorist attacks and sponsor a spent fuel storage (wet and dry storage) security risk assessment for U.S. nuclear plants. (4.1)
- The independent examination of surveillance and security measures for protecting stored spent should include an examination of the effectiveness of the U.S. Nuclear Regulatory Commission's programs for mitigating insider threats. (4.3)
- Reexamine the need for the 60-day limit for fuel dispersion in pools after reactor offloads and reduce the allowable time if feasible. (4.8)
- Reexamine and, if needed, redesign the spent fuel pool water makeup and spray systems and strategies to ensure that they can be implemented when physical access to pools is hindered or the site becomes inaccessible. (4.8)
- Sponsor an end-to-end validation of the MELCOR code for use in modeling coolant loss in spent fuel pools, and (2) validate key submodels in the code. (4.6)
- Give high priority to completing its analyses on dry cask storage vulnerabilities and rulemaking. (4.10)

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NRC Staff Review and Response to National Academy of Sciences Study of the Lessons Learned from the Fukushima Nuclear Accident (SECY-16-0100)

ACRS Fukushima Subcommittee Meeting
November 30, 2016

Japan Lessons Learned

Background

- Consolidated Appropriations Act of 2012
- NAS study organized to address:
  1) causes of the Fukushima nuclear accident
  2) reevaluation of the conclusions from previous NAS studies (2003-2004 Study)
  3) lessons to improve commercial nuclear plant safety and security systems and operations
  4) lessons to improve commercial nuclear plant safety and security regulations

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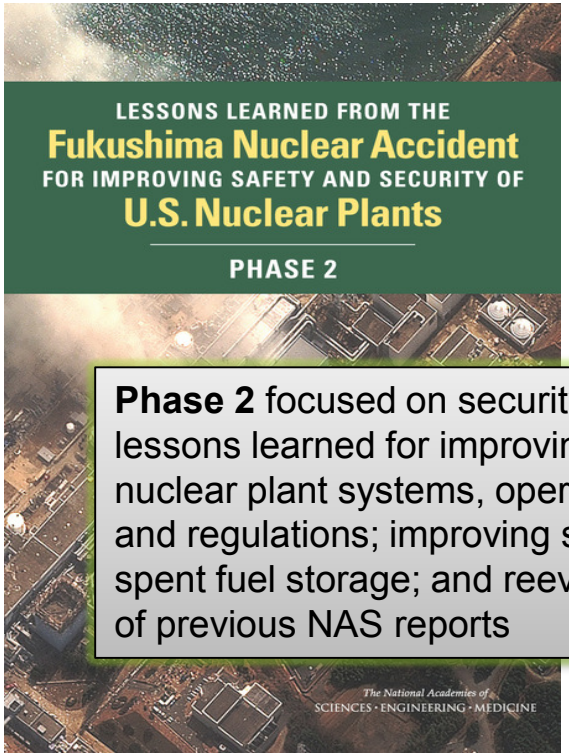
Background

Phase 1 focused on causes of the Fukushima Dai-ichi accident and safety-related lessons learned for improving nuclear plant systems, operations, and regulations exclusive of spent fuel storage



Phase 2 focused on security-related lessons learned for improving nuclear plant systems, operations, and regulations; improving safety of spent fuel storage; and reevaluation of previous NAS reports

NRC Staff Review/Responses

SECY-15-0059, Enclosure 6 **SECY-16-0100**

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Recommendation 2.1

Pool Monitoring and Cooling Capabilities

The U.S. nuclear industry and its regulator should give additional attention (i.e., beyond the current post-Fukushima response) to improving the ability of plant operators to measure real-time conditions in spent fuel pools and maintain adequate cooling of stored spent fuel during severe accidents and terrorist attacks.

- Similar to recommendation in NAS Phase 1 report; NRC required additional level indications (Order EA-12-051) and capabilities to mitigate loss of spent fuel pool cooling/inventory (Order EA-12-049)
- NRC considered requiring other instrumentation but determined actions taken adequately address lessons learned
- Post 9/11, NRC issued 10 CFR 50.54(hh), with guidance for deployment during dispersed and nondispersed configurations Enhanced by Order EA-12-049 and guidance (NEI 12-06)
- **Conclusion:** Additional requirements for instrumentation and makeup capabilities would not provide substantial increase in overall protection of public health and safety

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Recommendation 3.1

Security for Beyond-DB External Events

Nuclear plant operators and their regulators should upgrade and/or protect nuclear plant security infrastructure and systems and train security personnel to cope with extreme external events and severe accidents.

- Security systems include redundancies and backup power supplies and licensees have contingency plans if security systems degraded
- Improved mitigating strategies could be used during security threats concurrent with natural disaster
- Improved coordination within nuclear industry and with local and Federal agencies
- Unlikely to have security event coincident with natural disaster
- **Conclusion:** Additional requirements to address concurrent natural disaster and security events would not provide substantial increase in overall protection of public health and safety or the common defense and security

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Recommendation 4.1A

Strengthen Role of Risk Assessment in Security

The U.S. nuclear industry and the NRC should strengthen their capabilities for identifying, evaluating, and managing the risks from terrorist attacks.

- NRC has used and will continue to use risk insights in the security area
- NRC will cooperate with other Federal agencies to develop or use risk management approaches to protect critical infrastructure and key assets
- Post 9/11 requirements for managing the safety/security interface and mitigating strategies for loss of large areas of the plant due to explosions or fires
- Ongoing activities to enhance use of risk management and risk assessment techniques in the security area
- Revised Advanced Reactor Policy Statement

Recommendation 4.1A

Strengthen Role of Risk Assessment in Security (Continued)

The U.S. nuclear industry and the NRC should strengthen their capabilities for identifying, evaluating, and managing the risks from terrorist attacks.

- Asymmetric security threats would have effects similar to events addressed by design and operation (e.g., loss of offsite power) and unlikely to result in cascading failures leading to a radiological release
- **Conclusion:** Existing security requirements and NRC's continuous interactions with other Federal agencies sufficiently address security-related risks. Staff did not identify a need to initiate new activities or otherwise redirect resources.

Recommendation 4.1B

Sponsor Spent Fuel Security Risk Assessment

The NRC should sponsor a spent fuel storage (wet and dry storage) security risk assessment for U.S. nuclear plants.

- NRC interacting with other Federal agencies, International Atomic Energy Agency on nuclear security assessment methods, including spent fuel pools
- Security assessments performed following 9/11 included PRA-like insights in terms of event sequences and consequences, including analyses for several dry cask designs
- Similar finding and conclusion as for NAS 2006 report
- **Conclusion:** NAS observations consistent with others from within and outside of the NRC. Staff did not identify a need to initiate new activities or otherwise redirect resources.

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Recommendation 4.3

Independent Examination (including insider threats)

The NRC should obtain an independent examination of surveillance and security measures for protecting stored spent fuel as recommended by NAS (2006), including an examination of the effectiveness of the NRC's programs for mitigating insider threats.

- NRC establishes goals and measures and provides routine reports regarding its performance (safety and security)
- NRC works closely with other Federal agencies to identify and address possible security threats
- Independent assessments of NRC performed by OIG, GAO, and oversight bodies
- Insights into security and safety programs from operating experience, drills and exercises, inspections, international activities, and public interactions

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Recommendation 4.3

Independent Examination (including insider threats) (continued)

The NRC should obtain an independent examination of surveillance and security measures for protecting stored spent fuel as recommended by NAS (2006), including an examination of the effectiveness of the NRC's programs for mitigating insider threats.

- NRC has established requirements and oversees licensees' programs to protect against insider threats, including selected reinvestigations. Complimented by routine equipment surveillances.
- **Conclusion:** Not necessary to redirect resources to another independent assessment

Recommendation 4.6

End-to-end validation of MELCOR

The NRC should (1) sponsor an end-to-end validation of the MELCOR code for use in modeling coolant loss in spent fuel pools, and (2) validate key submodels in the code.

- Most important phenomena relevant to severe accident progression are mechanistically modeled in MELCOR, supported by experimental validation, and sufficient for regulatory applications
- MELCOR is a state-of-the-art tool to inform regulatory decisions, where uncertainties are appropriately considered
- MELCOR benchmarked against separate effect and integral tests for a wide range of phenomena (code manual Vol. 3 in ADAMS Accession Number ML15300A476)
- MELCOR assessments include series of experiments for spent fuel pool accidents conducted between 2004 and 2012 (See NUREG/CR-7143 (BWR) and NUREG/CR-7216/16 (PWR))

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Recommendation 4.6

End-to-end validation of MELCOR (continued)

The NRC should (1) sponsor an end-to-end validation of the MELCOR code for use in modeling coolant loss in spent fuel pools, and (2) validate key submodels in the code.

- Additional code assessment (e.g., partial draindown, spray modeling) can enhance code capabilities and modeling improvements are important and will be pursued. Ongoing research activities include:
  - Spent fuel pool project (DENOPI) coordinated by IRSN in France
  - Nuclear Energy Agency coordinating phenomena identification and ranking table (PIRT) development for SFP phenomena
- **Conclusion:** MELCOR models the most important severe accident phenomena, is supported by appropriate experimental validation, and is sufficient for current regulatory applications. Uncertainties in analysis tools will continue to be addressed when used to support regulatory decisions.

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Recommendation 4.8

Fuel dispersion and remote cooling capability

The NRC should take the following actions to more fully implement Rec. 3E-2 in the 2006 NAS report: (1) reexamine the need for the 60-day limit for fuel dispersion and reduce the allowable time if feasible, and (2) reexamine and, if needed, redesign the water makeup and spray systems and strategies to ensure that they can be implemented when physical access to pools is hindered or the site becomes inaccessible.

- SECY-14-0136, "Response to Commission Direction on Spent Fuel Pool Limited Term Operational Vulnerabilities"
- Post 9/11, NRC issued 10 CFR 50.54(hh). Related guidance includes deployment during dispersed and nondispersed configurations. Further enhanced by Order EA-12-049 and the guidance provided in NEI 12-06
- **Conclusion:** Additional studies of enhanced cooling capabilities and dispersion of spent fuel within pools unlikely to support additional regulatory requirements

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Recommendation 4.10

Dry Cask Storage Security Rulemaking

The NRC should give high priority to completing its analyses on dry cask storage vulnerabilities and rulemaking.

- COMSECY-15-0024 and related Commission decision on proposed rulemaking related to security requirements for facilities storing spent nuclear fuel
- Reflects evolving landscape, ongoing research, and coordination with decommissioning rulemaking
- Existing regulatory requirements and inspections provide high assurance of adequate protection
- **Conclusion:** Not necessary to reprioritize or reschedule activities related to ISFSI security rulemaking. Staff will continue to pursue improvements in regulatory and research programs.

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Recommendation 4.11

Risk Assessment for Expedited Transfer

The NRC should perform a spent fuel storage risk assessment to elucidate the risks and potential benefits of expedited transfer of spent fuel from pools to dry casks.

- Relatively recent studies available in NUREG-2161 (pools) and NUREG-1864 (dry cask)
- COMSECY-13-0030 and related Commission decision related to possibly expediting the transfer of spent fuel from pools to dry cask storage
- Plant security assessed in combination with but not fully integrated into PRA models, sabotage not included in expedited transfer assessments
- Limits on possible consequences too far attenuated from NRC's authority (e.g., alleged psychological impacts)
- **Conclusion:** Various analyses performed or sponsored by the NRC sufficient to support regulatory decisions on the safety and security of spent fuel pools.

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Questions / Discussion

Backup Slide

SFP Gate Seal Leakage

NAS discussion of Fukushima event: Pool water levels [Unit 4] would have dropped below the top of active fuel had there not been leakage of water into the pool from the reactor well and dryer/separator pit through the separating gates …

- Leakage into spent fuel pool from reactor well consistent with other assessments
  - TEPCO, ORNL, SNL
- Related NRC actions:
  - Order EA-12-051
  - Order EA-12-049 (enhancing 10 CFR 50.54(hh))
  - Hazard Reevaluations, Communications, etc.
- Leakage to or from spent fuel pool associated with gates addressed by NRC regulatory actions

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Backup Slide

Other Factors in Regulatory Assessments

NAS Recommendations, including 4.1A and 4.11, suggest consideration of psychological impacts as part of assessing offsite consequences of security scenarios

- Case Law
  - *Metropolitan Edison Co. v. People Against Nuclear Energy*
- SECY-12-0110
  - Consideration of Economic Consequences
- Broader discussions, including ACRS, on possible use of other societal measures