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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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REGULATORY POLICIES AND PRACTICES SUBCOMMITTEE

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THURSDAY

FEBRUARY 16, 2023

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The Subcommittee met via Teleconference, at 1:00 p.m. EST, Vicki M. Bier, Chair, presiding.

COMMITTEE MEMBERS:

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JOY L. REMPE, Member

MATTHEW W. SUNSERI, Member

ACRS CONSULTANTS:

DENNIS BLEY

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

HOSSEIN NOURBAKHSH

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

1:00 p.m.

CHAIR BIER: Well we should go ahead and get started, I think, because it is 1:00. So this meeting will now come to order.

This is a meeting of the Regulatory Policies and Practices Subcommittee of the Advisory Committee on Reactor Safeguards, in preparation for ACRS efforts exploring NRC safety goal policy. I am Vicki Bier. I am Chair of today's Subcommittee meeting.

Members in attendance, in no particular order, Joy Rempe, Ron Ballinger. I believe Jose and Charlie are both in the room there. I'm virtual so I haven't confirmed. You both back?

MEMBER BALLINGER: Ron is.

CHAIR BIER: Okay, great.

MR. MOORE: This is Scott. This is Scott Moore.

CHAIR BIER: Yes.

MR. MOORE: Jose will be back in a minute, he just stepped out briefly.

CHAIR BIER: Oh, perfect. Thank you for clarifying. Dave Petti, Walt Kirchner, Greg Halnon, Vesna Dimitrijevic, Matt Sunseri. And then we also have two consultants with us, Steve Schultz and Dennis Bley. Consultants to the Committee.

Have I missed anybody that I should have listed? Okay --

MR. MOORE: Did you mention Ron Ballinger is here in the room as well?

CHAIR BIER: I think I did get his name --

MR. MOORE: Okay, thank you. Sorry.

CHAIR BIER: -- earlier. Oh, no problem.

MR. MOORE: My mistake.

CHAIR BIER: Thanks for clarifying. Designated federal official for today's meeting is Hossein Nourbakhsh. And there will be time for public comment during the meeting, but people can also share any feedback with him after the meeting.

We are holding this meeting to gather information to support an ACRS working group exploring the quantitative health objectives in the safety goal policy. Right now this work is at a very preliminary stage, so we are just focused on gathering information and background.

We've invited Dr. David Johnson to present a perspective on the nuclear safety goals. Dave Johnson was an ACRS fellow at the time when the safety goals were initially developed and proposed by the

ACRS, working with David Okrent at that time.

And that work was the basis for the later NRC development of the safety goal policy. So we thought it would be interesting getting his perspective on both the history of safety goals, but he also has a lot of experience with PRA in the year since then, and reflect some on how he sees the current and future status as well.

The ACRS section of the U.S. NRC public website provides our charter, bylaws, agendas, letter reports and full transcript of all full and subcommittee meetings, including slides, like what Dave is going to present today. The meeting notice and agenda for this meeting were also posted there.

The Subcommittee will gather information, analyze relevant issues and facts and formulate proposed positions and actions as appropriate for deliberation by the full committee. A transcript of today's meeting is being kept, and will be made available.

Due to the COVID pandemic, today's meeting is being held in hybrid mode, with both in-person and remote Microsoft Teams capabilities. There is also a phone bridge line number allowing public members to participate over the phone as well.

Anybody making comments to the subcommittee should please first identify yourself and speak with sufficient clarity and volume so that you can be readily heard. When not speaking we request that participants mute their computer, microphone or telephone to reduce noise.

I think public comments are on the agenda for at about 2:00 or 2:10 today. And we may get to that a little earlier, but I will try and come back to that at that time in case anybody is planning their schedule around that.

And at this point we are ready to proceed with the meeting. And I will call upon Dave Johnson, our invited expert, to begin today's presentation. Dave, you can go ahead.

DR. JOHNSON: Great, thank you. And hopefully you can hear me clearly. I want to thank Vicki for inviting me. And before I forget, I want to say hello to Steve Schultz and Dennis Bley. And it's been quite a while.

So, my comment, I guess, is any relationship of the NRC goals to what the ACRS put together is not real clear. I mean, it's clear but it's just, the ACRS went much further in my opinion.

So, first a brief introduction. I want to walk through the history of the ACRS safety goals that was published in 1980. And then touch on some safety goals that my group developed for the research reactor in Australia in about '98.

I've had the good fortune to work on several research reactors from a PRA point of view. And when I think back on them I think there is, we can learn a lot from those activities as we move into new, innovative or old designs, whatever you want to call them, reactors that we're seeing come to fruition right now.

Very gratefully on the NRC PRAs, just at a high level how they were stated, et cetera. And finally talk about the really challenging things you guys have bitten off by trying to extend this work into the area of SMRs and microreactors. You know, I'm working on some great applications now. There is just a whole new environment for us to consider these days.

So, 1979, 1980 I was a fellow at the ACRS. 1979 I worked primarily with Dave Muller. And he and David Okrent were my sponsors. 1980 I went over to work with David, David Okrent.

So, what was the landscape at the time? There was a limited number of PRAs, we'll call it

PRAs, available at the time. Certainly the WASH 1400 final report, 1975. Oyster Creek in '78 came out. A kind of concurrent with a lot of this work between the Zion and Indian Point studies. And you'll see I pulled from some preliminary Zion work to think through some possible metrics for their safety goals.

I have got to say, the attitude in RCA regarding PRA, I'll be kind say it was mixed. There was a large number of people who didn't understand PRA and were embedded with the deterministic thinking. There is some very strong support with Bob Budnitz's role, et cetera. But there is quite a bit of hostility to trying to use PRA in anything that kind of felt like a regulatory environment.

And in the background of our work TMI had just occurred. You know, the ACRS at the time was located downtown. And about a week after I got there an event happened up at Maine Yankee, just a calculational error was found in a computer code and it resulted in hearings on the Hill. ACRS sent a GS-15 down there to gather up all the material and take notes, et cetera.

And I moved my big mouth and, gee, if anything like this happens again I'd love to do that. Well, TMI happened about a week later, so I spent way too much time listening to those folks. It's very disheartening to see how our laws are made quite frankly. Young people shouldn't do that.

Also kind of in background, there is inconsistent federal guidelines. There are radiation exposure limits in the laws which, let me just say, were science-based. Or at least science argued.

And then we had the Delaney Clause which at the time said, gee, if there is anything from an animal study or actual regulatory data, et cetera, that says that this is cancer causing materials it will not be in food, drugs or cosmetics. So there is an absolute limit, if you will. That's since been changed. Modified to something more reasonable. By the time that was the law.

So we were trying to, one of the things we did was look at the landscape of what other issues has the government sunk their fingers into. And those kind of represented the two extremes, if you will. Inconsistent.

So I'm trying to duplicate what the cover of the NUREG that we produced looked like. At least at that time the ACRS, when they approached me, came out with these Orange colored covers. They spelled the word committee correctly. I didn't when I made this slide up.

So the folks working on these goals were Mike Griesmeyer, myself. Bill Kastenberg did a sabbatical. But these here have some, of course the main driver behind this is David Okrent. You can see his fingerprints throughout the framework and the structure of the goals.

So one thing that I think I missed along the way, and I tried to pull up the relevant sentence there on top, you know, it's almost as if the Committee wrote these notes. The NRC rules and regulations, and staff documents dealing with safety, such as reg guides, et cetera, et cetera, represent a risk reduction philosophy without fully articulated safety goals.

So in other words, there is no framework for NRC to really consider the work that they were doing to establish and maintain safety. It seemed to be, gee, let's make things safer and safer and safer.

So the primary goal of the committee, there in black, was to provide NRC with a coherent framework for effective regulation. You know, it wasn't to add more regulatory issues for the licensees, it was really to provide guidance for the NRC.

And I'll say this a couple of times, the goals, or objectives, whatever words we're going to use, were not considered absolute when viewed in isolation. I think the words in there say that the plant would be expected to not exceed the limits in the long-term, but there could be excellent reasons for limits to be exceeded.

For example, you know, at the time I think we used an example of the time in New England there is a number of nuclear plants at the time. And if it was an exceptionally cold winter, in closing down one or two plants would cause hardship, or maybe even health effects or deaths in one population, certainly they would not closing down plants in the short-term. So these were to be used, these were not to be viewed isolation onsite.

So, a couple of forms of the decision rules. One that there are limits on certain hazardous states within the reactor. We'll get to each one of these. The limits on individual risk or early death or delayed death due to cancers. In societal risk of early death or delayed deaths due to cancers.

And you'll see it when we articulate the goals for the societal risks, there is a major risk aversion in that criteria. David Okrent was a big believer in risk aversion. We talked a lot about it.

You know, that's the philosophy that society has expressed a willingness to bait one bus crash that kills ten people more, or higher, a worse event if you will, than ten bus crashes that kill one person each. So that's a, you'll see a risk aversion factor sneak in here. ALARA was always present in these considerations.

Assume that the cancer deaths, and early deaths, would control radiological releases. And there other impacts that we can talk about. We talked about teratogenic effects, but we're only going to put early deaths and cancer deaths into the puzzle here.

So, there is a lot of library work done leading up to this work. There is a great body of research done in the '60s and '70s on issues of acceptable risk, and things like that.

Now I just pulled out of a few of them here. Adams and Stone said, gee, the changes in the risk ought to be small compared to the demographic variation, this happened to be in the U.K., from risk for dying of all other hazard sources. And so that leads you to something like ten to the minus five per year for an individual.

Kind of the classic case was a Farmer and the Farmer Curve. There was a frequency release curve, a frequency of curies of iodine if you will. And my understanding is this came about at a response to the once fatal accident when they were trying to find a rational basis for how far do we need to go out and interdict the sheep and livestock to protect the health and safety of the public. But this is a classic case of risk acceptance, or risk measurement, if you will.

Bowen I liked quite a bit because it emphasized that the risks ought to be smaller than the benefits gained by the technology.

DR. BLEY: Hey, Dave, can I interrupt you?

DR. JOHNSON: Yes, sir. Dennis.

DR. BLEY: My memory might be off on this. This might have been somebody else applying Farmer's work. But I thought the Farmer Curve had a knee in it to throw in some risk aversion effects too?

DR. JOHNSON: Yes. It's not -- I believe it does. It does have a risk aversion effect, but it did have a knee in it. I didn't know the source event. And I no longer have a copy of the curve itself. So that's a good point.

So on the risk being smaller, damaged by the technology, I was going to talk more about this at the end, and I just kind of ran out of time. I figured you'd be tired of me talking by then.

But we're talking about some of the new nuclear applications being connected to specific technology such as reducing ammonia for fuel or hydrogen for fuel. And if you can imagine 800 degrees sea steam going into an industrial building, you know, where do you draw the limits in terms of doing the risk assessment for this process.

I just became aware of an environment defense counsel's paper. It's peer reviewed, it's way outside my field, that suggests that hydrogen being very hard to contain, which is true., if it were to get up into the upper atmosphere it could be the granddaddy of all carbon issues or, what am I trying to say, climate change gases that we've ever released in our life. So, we could be rushing into things not knowing.

So the risks, we need to keep in the mind the risks that we're setting aside. You know, maybe sticking with replacing old coal plants might be a thing to do.

And finally I just want to mention, the benefit for me is with a number of experiments. But the two that really stuck out of my mind were Bill

Lowrance who had just finished a book called, Of Acceptable Risk. And talked about how people in societies understand, grow to understand risk. And neither accept them or put them into special categories.

And Paul Slavic who really kind of helped straighten out ideas with risk perception when it came to technical risks.

So, we explored a number of different methods. Let me drink water here. And one that was violently rejected by a committee member who, up until that time was a very mild manner guy in my book.

So I presented an idea that really started with the question of, why is it we do PRA. And I thought there at the time my thinking was, there was two key reasons. One is to come up with a rank ordered list of scenarios that contribute to something bad and understanding where those scenarios came from, what you can do about them, and that sort of thing.

And the second thing is to really identify and understand sources of uncertainty. You know, we're dealing with large uncertainties in the case.

So I thought it would be prudent to talk about a metric that really focused on uncertainty. And what I did, the best PRA that I could put my fingers on at the time was Zion. At least a very preliminary version of Zion. This is not what the CDF for Zion looked like, that's what I was able to recreate for this presentation.

But I thought, well, why don't we put some sort of measure on the median value of this metric CDF, then something adding a tail. And I know the 95th was getting kind of swirly, and I arbitrarily put the 85th. And when I said they were arbitrary that's when the, Jeremiah Ray was the, who was my old member who went berserk, anyway, there is, committee enjoyed this presentation. But they basically backed off and accepted Jeremiah's recommendation that we not do something explicitly with uncertainty curves.

And I really thought that we missed an opportunity there because, in my reading, uncertainty gets a lot of lip service but is not really focused on, as a keen interest.

So anyway, the two numbers from Zion, that would be ten to the minus four and eight times ten to the -- five times to the minus 85th. And you'll see those numbers again here pretty soon.

So was left, you know, after the, the my wounds healed up, what we decided to do was take those two numbers, in the middle of column, middle row here, field damage, and use the smaller one to set a goal of one times the last four, and the upper one as a limit. And in-between it's kind of business as usual. You know, there is, it's kind of fuzzy, if you will.

And I can tell you when Reg Guide 1.174 came out they used this same kind of framework and growth once more. But the argument was by accepting a range we're kind of embracing uncertainty. And I actually still don't believe that.

And the other goal, was has not been used anywhere that I can see, is what is called significant core damage. But basically noble gases and things like that. About a factor of three more often, if you will, than the large scale fuel damage.

Now why it might be of particular interest these days, although it's a more complex issue, is that, I'm thinking that your goals, let's say your framework today, is going to have to embrace a number of different technologies. Including molten fuel reactors. Okay?

And we know the molten salt reactor experiment at Oak Ridge had a special system that gathered up the noble gasses (audio interference) and not have a significant issue with the core itself. So, there may be a different category of events that we need to consider.

And finally, the last row is we've seen is a sort of conditional core damage -- conditional containment, if you will. And once again, I want to emphasize that everything the committee did indicated that compliance with the upper limit was anticipated. And it was required for extended operation. But there could be reasons where a plant could operate outside this framework for a period of time.

So for individuals, the most exposed individual, there is limits on the cancer, cancer deaths, as well as early deaths due to accidents. And this was over the lifetime of the reactor. And considering all reactors at a particular site.

So, I won't go through read the goals here, but you'll see that the goals are specified, both in terms of goals and limits. You know, something on the order of ten to the minus five-ish. Or ten to the minus something times seven to the minus six.

For reference, individuals at the time, the best data we had the time, individuals with cancer death risk was something on the order of 15 or 20 percent. I'm not sure what it is today. It could be more or less. But anyway, the message here is it's a small increment to existing risks due to cancer.

Likewise for early deaths, the numbers were in the order of ten to the minus six, five to the minus six, et cetera. And for reference, the safest demographic to be, again, at the time, this was probably data from the, oh, '60s and '70s would be a 14, a 10 to 14-year-old-girl with having an accidental death rate of about ten to the minus four.

Likewise, societal risks were specified in terms of the goals and limits. I won't go through here, but just pointing out that the accidental deaths were specified with a risk aversion with Alpha. With is the exponent in the equation, of 1.2.

We did do --

MEMBER KIRCHNER: David?

(Simultaneous speaking.)

MEMBER KIRCHNER: Dave, this is Walt Kirchner.

DR. JOHNSON: Yes, sir.

MEMBER KIRCHNER: Could you just explain this chart? This is interesting because it references kilowatt hours. Could you just elaborate a little more how this was developed?

DR. JOHNSON: I could if I remembered. Let me just think for a second. I was looking at it this morning and was trying to figure out a couple aspects of this, but quite frankly I don't recall why we choose that metric.

MEMBER KIRCHNER: Well, it looks like the integrated power that was produced by the reactor fleet --

DR. JOHNSON: Yes.

MEMBER KIRCHNER: -- or at a site or --

DR. SCHULTZ: Dave?

DR. JOHNSON: Yes.

DR. SCHULTZ: Dave, this is Steve Schultz. Ten to the 10th kilowatt hours is approximately one year of reactor operation at 1200 megawatts.

DR. JOHNSON: Yes.

DR. SCHULTZ: Yes.

DR. JOHNSON: I did figure that out. I don't know why we choose to express it in those terms. So --

MEMBER PETTI: Is it because it's related to a fraction of the cancer? A fraction of the deaths from coal?

DR. JOHNSON: Well, it was, we did compare it to what we thought were the best estimates for coal. That may have been the reason why we went to kilowatt hours. But it's a little confusing here to represent this one in terms of kilowatt hours when the other charts were not this way. I do not know. A new and smarter committee can clean this up.

(Laughter.)

CHAIR BIER: But that is a very interesting bit of historical background we can probably dig out. The source for that and some of the documents at the time. Maybe not the rationale but at least the precedent that it was based per --

DR. JOHNSON: It could be one of the appendices to the NUREG --

CHAIR BIER: Yes.

DR. JOHNSON: -- as an attempt to apply the goals, if you will, to a coal plant. And I just summarized that at the bottom is, you know, the same metric applied to a similar status coal plant would result in --

CHAIR BIER: Right.

DR. JOHNSON: -- it says 10 to 200 excess deaths per year.

CHAIR BIER: So I have been trying to collect a little mini library of documentation of the historic analysis, so I will try and see if I can dig that out.

DR. JOHNSON: Yes. There is, I believe

quite an extensive bibliography in the NUREG.

DR. BLEY: Hey, Dave? It's Dennis. Just two quick things here. The one is, like everybody else pointed out, you did a comparison essentially with a coal plant running for a year.

There is a bit of a story that the goals were set to be a fraction of a coal plant's output. And maybe that's not the right thing to do these days, but --

(Simultaneous speaking.)

DR. BLEY: -- really saying it comes from other sources, and you just did a comparison with coal plants to see how they --

(Simultaneous speaking.)

DR. JOHNSON: Yes.

DR. BLEY: -- stood up again.

DR. JOHNSON: -- we started off thinking that it would be appropriate to get a closer comparison to coal plants. And that may make that be the driving factor, if you will. But we soon realized that the coal plant data we had was publicly coal technology from the 1960s.

CHAIR BIER: Right.

DR. JOHNSON: And, you know, things, that will change. And is it really fair to make that comparison anyways.

And if I backed up several slides the literature seem to aim you toward if you're establishing a new technology to make the incremental risks to be very small compared to things like the variation of nature and other risks or essentially non-traceable. You know, non-observable. It would be an analytical number if you will.

So we decided it was not fair to really kind of point a finger and say, look the coal plants are worse, we can do this and that, when we felt that the technology itself had some very inherent attractive features from this point of view. But I think it is appropriate to make a comparison, but not to base the limits on other technologies. If that makes sense.

DR. BLEY: It does to me. And it kind of clears the argument that's been floating around.

DR. JOHNSON: We talked about a, you know, basing it on coal. That was one of their only discussions. And it may have been the reason why we wrote a separate appendix on the document that actually did that comparison.

We didn't, you know, we didn't want to alienate -- first of all, our audience for this was not to put additional requirements on the owner/operators of power plants, it was to help provide NRC with a framework to kind of organize their regulations. But we didn't want to survive the feedback that if we were telling a company that had, at an earlier plant, that, gee, that one of there was lousy.

It was not our business, okay? We didn't want to get into that argument. We didn't have to. It turns out we didn't have to. We probably spent way too much time worrying that through, but.

DR. SCHULTZ: Dave, this is Steve Schultz. Just to comment. This is, 1980 was just about the time that EPRI was spending a lot of effort looking at scrubber technology of coal.

DR. JOHNSON: Right. Right. Yes, the coal plants, you'll see the data in that appendix from is, I would say at best '60s technology. Maybe even earlier than that. They've come a long way. It would not have been good to tie your reference to a moving target.

So just a last couple of comments here. There is a lot of good stuff, and I went back and read this document, I hadn't read it in years and years. Some additional requirements, special attention should be paid to the delay of the PRAs. Full and explicit duplication of assumptions and limitations. And peer reviews must be done.

Well, this was 1980. You know, 15 years later the PRA procedure's guide, not procedure guide, but standards come out. And these are key elements of that. So, early on the Committee was calling for that sort of thing.

There is an additional discussion in there. And this has got Dave written all over it, is we really ought to establish a risk certification panel that would have statutory authority to make judgements, technical judgements on technical issues.

He was a great believer in science court. I'm not sure it would have ever been a good idea given our politics.

DR. SCHULTZ: Yes.

DR. JOHNSON: But he was adamant that the people who say that the PRA is good need to have specific qualifications. And in his mind, even statutory authority to say so. I don't think we've --

DR. BLEY: So that idea, and EPRI is the volunteer, Chauncey Starr was a big fan of that as well as I recall.

DR. JOHNSON: Absolutely. Yes.

MEMBER REMPE: So thanks for interrupting me. Did it go beyond nuclear?

People do risk assessments for his plants, did he want it to be an across the board or just in --

DR. JOHNSON: Oh --

(Simultaneous speaking.)

DR. JOHNSON: The science court would be across the board. It would be --

MEMBER REMPE: Okay.

DR. JOHNSON: -- technical issues that affects society.

MEMBER REMPE: It's interesting. Thanks.

DR. JOHNSON: And I, you know, the problem of course is, that Dennis and I could come to an agreement who should be on that panel. And we disagree with anybody who disagrees with us. So that's a tough one, tough one.

MEMBER REMPE: Okay.

DR. JOHNSON: But the idea that the qualified loop is to have that say it's still a viable one.

Okay, just the last slide on the historical stuff. Really, on the individual cancer deaths where it's explicitly considered for all reactors at a given site.

I don't know why we did that quite frankly, but that's in there. And while the Zion PRA is best I can find at the time, it's full scope, internal events, external events, Level 3, things like shutdown were not appreciated and not included in that.

(Off-microphone comments.)

DR. JOHNSON: Well, on one hand we've made (audio interference) -- was there a question?

MR. MOORE: This is Scott Moore, executive director. No, there wasn't a question, that was the court reporter saying --

DR. JOHNSON: Oh.

MR. MOORE: -- that he couldn't hear your delivery because somebody else is on line.

DR. JOHNSON: Okay.

CHAIR BIER: Yes.

MR. MOORE: Has a mic open.

CHAIR BIER: So if you want, Dave, you can go back and repeat your last sentence or two of points.

DR. JOHNSON: Okay. So, all I was saying is that, for whatever reason, and I don't remember the rationale at this point, but only individual risk and cancer death was considered for all reactors at a given site. I'm not sure why we did that. In reflection it doesn't seem to be consistent.

And then I was saying that while the Zion PRA was the best thing I could put my fingers on at the time, it was a full scope PRA. Really state of the art, Level 3. It did not include things like shutdown risk. Later on I'm going to bring up the role of security risk. We certainly didn't include that.

And while advancements have been made in things like fire PRA and that sort of thing, I happen to think that the way that they treated human error in the Zion PRA is at least as good as the way that standard approaches are now. But that's just my own opinion.

Anyway, things have changed since then. Coal located technologies were not considered. I think that could be an issue when you guys are moving forward. And while coal provided a benchmark for some measures, nothing that we built the limits and goals off of, but coal is referred to in there. Nuclear replacing existing technology is not considered.

And based on --

CHAIR BIER: Dave?

DR. JOHNSON: Yes.

CHAIR BIER: There's a question from Joy when you're ready for it.

MEMBER REMPE: This is Joy. And I wanted him to finish the slide, but I do have a lot of questions here.

CHAIR BIER: Okay.

MEMBER REMPE: But go ahead, Dave. Sorry for --

(Simultaneous speaking.)

DR. JOHNSON: -- almost finished. I'll just finish the slide. And I, it's my pet peeve, but I think we missed a great chance to provide the appropriate amount of attention in the PRA world to uncertainty. Okay, I'm ready for your question.

MEMBER REMPE: Okay. Because you're going to switch topics, I have some other questions that I'm just curious and I'd like your insights a little bit more.

When they were thinking about this, and as you look at the hindsight thing, I'm curious if you had any more insights on why that multiple units were only considered with the individual risks. Could you talk about, did they think at all about land contamination?

DR. JOHNSON: No. No.

MEMBER REMPE: Psychological risks? And then finally, when they were formulating this, did they think about what might happen if folks wanted to change it in the future and the effects on regulatory stability?

Because one of my thoughts is we, we're just gathering information. It's not clear we're going to come up with any great ideas that might help with some of the non-LWRs or other kinds of technologies, but what has used this framework for making decisions for cost benefit types of changes. And was the ACRS smart enough back when they did this to think about, once you do this, what if you wanted to make changes?

And so, I've got a lot of questions, but I've been holding them back as this was the place where I wanted to bring them up.

DR. JOHNSON: So, on the other measurements, like land contamination, et cetera, so the only offsite, that measurement was the early deaths and cancer deaths. Like I said, we didn't consider genetic effects, teratogenic effects, et cetera. Land contamination. Those were not considered without, you know, we just said we didn't consider them.

Maybe they ought to be the primary considerations. And given what we learned in Fukushima, maybe the land contamination ought to be a primary measurement. I mean, that's an excellent point.

In terms of regulatory stability, that was not discussed. We were trying to get NRC focused on regulatory, what's a polite word. Rationale. We're just trying to get it stabilized. In other words, every, not every, but it seemed like many of the regulations that would get propagated, were propagated because, let's do it because we can do it without any rationale of why it is we're doing that, well really it was the right thing to do or, you know, or we're causing a bigger problem somewhere else.

So I can tell you regulatory stability was not there. It was regulatory, a regulatory framework to provide some sort of coherent rationale behavior on the part of NRC.

MEMBER REMPE: So, again --

DR. JOHNSON: Does that --

MEMBER REMPE: -- I'm kind of throwing a lot of things at you, but they were aware of the fact that you have Peach Bottom with several units, and some of the other plants with multiple units and they didn't think about, except for this individual risk, to consider all of the reactors at site.

DR. JOHNSON: No, that was --

MEMBER REMPE: They did --

DR. JOHNSON: That was not thought of deeply, other than we need to consider the whole of the facility there. I don't think we understood that it's possible to have multiple acute accidents at the same time, which I think we understand that's possible now. So it was probably, you know, shoot, we ought to be looking at the long-term effects perhaps.

Those are good points. And I think maybe we need to go back and start with a fresh piece of paper and consider that. I was certain --

(Simultaneous speaking.)

MEMBER REMPE: -- know what you were thinking --

DR. JOHNSON: -- I was certain --

MEMBER REMPE: -- at the time, so I appreciate it. But go, I didn't mean to interrupt you I thought you were done. Go ahead.

DR. JOHNSON: No, no. I would certainly support the idea of land contamination being a primary measurement, if you will.

MEMBER REMPE: Thank you. Again, I

appreciate you coming in and talking with us today.

DR. JOHNSON: You know, I need to point out that I haven't slept since then. So it's not, this is 43 years ago.

(Laughter.)

MEMBER REMPE: I have problems with things too in the past. Thank you.

MEMBER KIRCHNER: Dave, this is Walt Kirchner. Just an observation on that last slide. I guess co-located technologies weren't explicitly included, but they are indirectly, even back then, for the citing of the plants. You did have to consider --

DR. JOHNSON: Oh, no, absolutely.

MEMBER KIRCHNER: -- nearby, nearby hazards and so on that would potentially, well, you just designed by either citing distance and/or hardening of structures to withstand glass and other effects. So, indirectly, I'm just highlighting that because now we have concepts that are considering hydrogen generation.

DR. JOHNSON: But you --

MEMBER KIRCHNER: And in the past, what you wanted to do is put as much distance between your power plant and, let's say gas lines and other potential blasts or hazards, so that they're kind of indirectly considered in, as a contributor to a potential Level 3 PRA. Just an observation.

DR. JOHNSON: No, no, you're absolutely right. They're considered in the sense of, how can these technologies harm my plant. I'm thinking here is, how can the plant intimately connect in with a different technology, have some problems that we didn't consider historically.

And I'm kind of jumping ahead in my mind I guess when I wrote that because I'm working with some people that are considering exactly that type of connection.

Okay, I'm behind the curve here so let me go through this one pretty quickly. Just to say that a number of years later working in Australia, on their research reactor there, is the last DIDO class reactor around. So they're an old, old reactor.

Ten megawatts thermal, heavy water cooled, heavy water moderated, graphite reflected. Light water, secondary circuit was light water. And the ultimate heat sink was basically evaporation into the atmosphere. It was high enriched uranium fuel. So the fuel was kind of touchy, if you will. Changed to low enrichment in 2006. Shutdown 2007. I don't know if it was two observations or independent.

We did the PRA in '98, along with a probabilistic remaining life study since it was such an old plant. And so, it was what we called a (audio interference) PRA. It looked at fuel damage for different sources plus characterizing the state of containment.

And so, they wanted a rationale for what kind of numbers to throw out there. And these would be more fuel damage numbers because that's the only thing we'd be looking at. At the time OECD, you know, was throwing out goals of ten to the minus four, ten to the minus five.

As of that time, as of November '95, something like 14 of 77 plants in the U.S. reported an informal, reported CDFs greater than informal limit of ten to the minus four.

And the other research reactor risk assessment of any, that I knew about at the time, well, that's not true, U.K. had one also. But when we did it in HIFR was a 100 megawatt plant changed to 85 megawatts. But it had a CDF around, in the low minus fours in the plant.

DR. BLEY: Hey, Dave?

DR. JOHNSON: There was -- excuse me?

DR. BLEY: Just, for the members, that one being a much higher ought not be a surprise because as I recall that machine was expected to have a core damage accident every couple of years when they first designed it.

DR. JOHNSON: Yes, I can talk for an hour and a half on that. I'm still working on that one.

But HIFR had just, well, not just completed, but a month or two ago completed a 500-fuel cycle. So, fuel lasts about 26 days there. It's an incredible machine. It's aluminum-based fuel with a U308 and aluminum matrix. The 550 fuel plates are 50 mils thick. The cooling channels are 50 mils. The power density is something like a megawatt a liter with aluminum fuel.

So yes, when they, if you look at the primary system, it's incredible robust, thick. And the reason is, they didn't know whether the fuel would hang together or just plate out on the primary system. And they'd fix it and start up again. So it's an incredible machine. A very important machine from a research point of view.

The first one where we did a fuel manufactured risk assessment for it. Which was kind of incredible.

But you can divert my attention by getting me to talk about HIFR all day. But so, just for a reference, if you will, it was easy to talk to the Australians about goals and limits and guides and things like that because they have a framework for risk acceptance, if you will, for essentially any activities that you can think of. And this is taken from one of their charts like, the U.K. does this too.

And I'm just happy that old age housing has got the least risky measure there. I'm getting into that time frame.

The reason I really wanted to bring this up is that we developed guidelines for the specific technology and the specific activities that were going on. True. True we have limits that we argued for damage to the, damage frequency to fuel in the core or fuel in a closed in storage block with reasonably fresh fuel. And fuel in a different storage block with and without containment failures et cetera.

But we noticed a number of other activities that they performed there that can lead to, I would call it more unanalyzed conditions. Mechanical damage to one or more fuel elements. They move these fuel elements during power operation. What they call flask. A heavy object that they move over storage fuel, et cetera.

And since it's a heavy water plant, tritium is an issue. It should be contained in a primary system, but historically they've had heat exchanger leaks getting some of the material into the secondary system. Which is essentially evaporating in the air.

And I didn't want to present their results, but I can say that it was the tritium releases that, to the environment, that exceeded the goals that we agreed on before we did the study. But here's a plant that's a lower power level, wise power level. Low primary system pressure, but with limited analysis for a number of reasonably interesting scenarios. So we put specific limits, if you will, frequency of those scenarios coming to pass.

And that could be a useful mechanism going forward when we're looking at oddball different plants in the future.

I think I only have one slide --

MEMBER KIRCHNER: Dave?

DR. JOHNSON: Yes.

MEMBER KIRCHNER: Dave, before you go on. This is Walt Kirchner again. It's interesting that that reactor, it's graphite moderated, heavy water moderator, heavy water secondary?

MEMBER PETTI: It's beryllium moderated I think.

MEMBER KIRCHNER: Beryllium moderated.

DR. JOHNSON: It was --

(Simultaneous speaking.)

MEMBER KIRCHNER: Did you uncover in your analyses, Dave, that there is the potential for it being over moderated?

DR. JOHNSON: We did not.

MEMBER KIRCHNER: Wow. I was just wondering whether that, one of those scenarios might have come up in your PRA work for that particular design. Which would lead to a reactivity insertion I assume.

DR. JOHNSON: Well this has to be one reference that I do have. Like I said to Vicki. I'm going to say we did not, but I'm not, I would have to go back and search the report.

MEMBER PETTI: As I recall, a mechanical damage aspect. I mean, they've had problems at the HIFR and other reactors of similar ilk with the fuel. I mean, it sits on the edge. The margin to damage is not, you know, it's not very large. Just because they need the high neutron flux and that's part of the mission. You -- there's acceptable risk that's different.

DR. JOHNSON: Yes. In this last year they've had several fuel issues.

MEMBER PETTI: Yes.

DR. JOHNSON: I have my own theory. I, you know, I've been involved in chasing those. Back in the '60s and '70s and '80s when you had some old greasy guys making the fuel over in Virginia, never had a problem whatsoever. Now we have a new generation guys with new computer driven ways and we've had all sorts of problems. So let's hear it for the old guys.

But yes, the fuel in HIFR is right on the edge. It is a water cell system. And if you bleed off the worst thing that can happen, well, one of the worst things that can happen, is that you have a leak. And if you bleed off not more than a few gallons, you'll go through a critical leak blocks and the core will relocate. So, yes, it's a very high performance machine.

So, I just have one slide on the safety goals because I figured you guys were well aware of it. You can say that there is a similarity between this and these risk goals. You can say that.

It's the pretty, at least the original

1986 ones, are pretty thin in a way. But there is qualitative and quantitative. Qualitative is the rationale. No significant additional risk to the life, to life or any individuals.

And in here they say that societal risk to health should be comparable to less than risk of generating electricity by viable comparable means and should not be a significant addition to other societal risks. So it's that second cause there that governs that. The numbers here, if you will. But other than that, the numbers are about the same.

Several places, I went back to the '86 Federal Reserve, Federal Register description. A couple of places they make it clear that zero is the number they want. No additional risks in the curve.

And it kind of made me feel like the Delaney Clause all over again. I'm not sure if they were just being politically correct in saying, in not wanting to say that, you know, technology offers benefits but also offers risks and we either accept that or not. But it was a very strange reading at almost 40 years later. A very strange way they worded things.

One Commissioner, Asselstine, did have a very interesting additional set of comments which I thought were spot on, is that basically we're missing the chance here to talk about the relevant emphasis of accident prevention versus accident mitigation and however to balance it. I thought that was, given how thin the other parts of the goals are in my opinion, that was quite interesting.

So, looking at the challenges you guys have going forward, you have new technologies, or the rediscovery of old technologies. You have the spectrum of reactor sizes, all sorts of reactor pressures from essentially atmospheric to the ones that we're looking at now. Larger numbers of reactors at sites. Or in combinations. Mobile reactors.

I should say the additional point is different environments. There is people considering what it would take to, let's say, reintroduce reactors into the marine business. Either providing electricity, provide power for ships in port or providing nearby creation of ammonia or hydrogen. Or near offshore applications to even mobile reactors on ships.

There is a huge number of barriers that need to get solved before we go down that spectrum. But there are people working on that sort of stuff.

One of the things is, our experience with

LWRs, which I think you all probably recognize is creating a bias in terms of how we think about reactors and risk, et cetera. You know, for example, what would Level 1 mean for a molten fuel molten salt reactor or a helium cooled reactor that has the TRISO coded fuel.

Carl Fleming has tried to explain to me several times that fuel hang together long after the primary system has failed in an event.

And how should we treat co-located technologies. And these are not things, like Walt was saying, a nearby chemical plant or nearby industrial facility, that these, my mind here is things that are connected, if you will, to the reactor. The reactor's purpose being, to provide district heating, 800 degrees sea steam for hydrogen production is just one.

And something that Dennis was saying, or asking about, does a nuclear facility get credit for replacing existing technologies. For example, should we compare it to coal, diesel, diesel being what's under in our ports, the answer is no. But they do provide a nice referenced event, but they shouldn't provide the basis for, for the analyses.

So, something I've been thinking about quite a bit, actually, for several years now, are the security scenarios that are specified on existing power plants out there. 10 CFR Part 73 type stuff. There are similar issues in some of the newer regulations that are being formulated out there.

And I understand that NRC is leaning toward specifying security requirements that are appropriate to the risk that the technology represents. Whatever the hell that means. I'm not sure what that really means.

But we've let the security issues at a terrestrial power plant kind of go independent. It's not something the PRA group, for example, really gets their fingers into. But the NRC and San Clear (phonetic), whoever comes and says, oh, here is your new set of scenarios regard against, you know, show that you can repel this sort of invasion, et cetera.

These are incredible expensive requirements on a power plant. And to not be risk-informed in any way, shape or form. I know that the one or two power plants where I understood what the requirements were, I could tell you that if they were to go to talk to the PRA people, A, they would have a much more interesting set of targets to postulate. But B, they operate in an independent world, if you will.

So my question for a long time has been, why aren't those scenarios considered within the PRA framework? After all, they start with initiating event, they go through a process of successes and failures and they end with an end state.

You can say it's a different beast, yes. And if we understood uncertainty better we could embrace that. It's a dynamic scenario. The initiating event is affected by the current state of affairs if you will. That's fine, we can handle that.

So I guess two questions. One, why aren't those considered as a more integral part of the risk scenario?

And two is, if we don't get our act together and develop a coherent set of regulations and approaches for these scenarios, these security scenarios, we're going to preclude a fair number of possible implications out there. Which might be the appropriate thing. I happen to think not. But that's just my question, is why are those considered differently?

Somebody at a plant told me that something like 15, ten to 15 percent of their OEM costs are associated with their security forces. So, you know, but there have been PRAs done, not from my mind, at least I have not done one for a nuclear plant, but they have been don't for other facilities. They could easily be done, in my opinion.

DR. BLEY: Dave?

DR. JOHNSON: So -- yes.

DR. BLEY: Dave? This is Dennis. Your previous bullet, the top one of this page, I take it that was your answer. And I'm a little curious about that because I'm thinking back to another technology. When I first moved to Southern California in 1979, smog days were most of the year. You could hardly see the mountains except for a few days around Christmas.

The Air Quality Management District, AQMD, was invented and started doing these tradeoffs to get credits for replacing air polluters with other more modern technology. And in about 15 years, by the mid-'90s when I left, the situation was completely reverse. There were only a few days a year where the air was really bad and the rest of the time it was good. They had great success.

They had a lot of opposition at first, you shouldn't be doing tradeoffs, you should just be getting rid of the bad actors. But that gave an incentive and it was really successful. So I'm curious about, why we shouldn't think about giving credit --

DR. JOHNSON: Well I --

(Simultaneous speaking.)

DR. JOHNSON: Yes, that was my answer and not the Committees or anything else. I was thinking back on, we can make our technology, I think, in a cost effective way, very attractive. And without denigrating other technologies who are also on an improvement path, if you will.

The marine industry is recognizing that their a huge air polluter with what they burn at sea, and in port, et cetera. But I don't want to, I don't think it's necessary to compare diesel emissions to a small nuclear plant, for example.

But yes, you could, I think referencing the risks that are being replaced provides a great framework, you know. But not basing on, not basing the acceptability of your new technology on replacement.

Let me --

DR. BLEY: Okay, thanks, I get where you're coming from. I'm not sure I wholly agree with it, but okay.

DR. JOHNSON: Oh, we've disagreed before some. And I'm okay with it.

(Laughter.)

CHAIR BIER: So, Dave, are you done with your prepared remarks?

DR. JOHNSON: No, I have two more if you would.

CHAIR BIER: Okay. So go ahead.

DR. JOHNSON: The last set of bullets on this page is one that's designed to make everybody on both sides of the equation angry at me.

So we had an advantage looking at it in hindsight that very many people were fluent in PRA back in the '77,'80 timeframe. Now everybody thinks they're gone, so. But I'm just stunned by the fact that, when I hear some industry folks talk, that they seem to be reluctant to embrace PRA when I think it would be one of the best tools they have in their tool box for design.

And on the other hand, you know, when I look at my cursory reading, I should say, of Option B of the Part 53, it sort of sounds like PRA, but it's not. So I'm not sure if I don't -- if I no longer understand what PRA is, or not very many people seem to.

And the reference there, HPRR, is a health physics research reactor, that's no longer there either, but it was an old Godiva class reactor. I think the PRA was 50 pages. So don't tell me I've got a simple plant, and simple design, and I'm not going to spend mega bucks doing a PRA. You know, you would be silly to --

MEMBER PETTI: Dave, I actually do think, I agree with you here. The people that are saying they don't -- there's a lot of people who don't want to do a PRA, because they think it will cost them a lot of money, because light water reactor PRAs cost a lot of money. These newer systems are smaller, they're simpler. I agree with you. The PRA should be simpler in principle.

DR. JOHNSON: Oh, absolutely.

MEMBER PETTI: And that just isn't getting out there to certain parts of the community.

DR. JOHNSON: Yeah. So I'm stunned that both the designers, not all of them but some of them, some of the ones that I'm working with, theoretically that they haven't seen it. But anyway, it just stuns me.

And then this Part B, Topic B of Part 53, I'm not sure what the hell that is quite frankly. So anyway --

MEMBER PETTI: Yeah. If we don't clarify

a path to licensing, we can have the ability to manufacture these things in a cost effective way. And they could, on paper, have a great risk signature and be all, you know, proven to be economical. But if we remain fuzzy on the licensing rules, these things will never see light of day. Anyway --

DR. JOHNSON: One last slide, and it's things we've already covered that I just tried to gather out the lighter task that is harder than my task. Reactor designs are very -- in hindsight we ignored Fort St. Vrain. It was around, we just, I can't remember any discussion once I thought about it. And we talked about these other things, about the different types of fuels, et cetera.

I'm done, Vicki.

CHAIR BIER: Okay. So we are more or less at perfect timing for any public comments at this time. And, yes, Edwin, thank you.

DR. LYMAN: Hello, this is Edwin Lyman from the Union of Concerned Scientists. Can you hear me?

CHAIR JOHNSON: Yes.

DR. LYMAN: Thanks. So I'd like to say I think the ACRS is, this is a very valuable activity, and we're very glad that you are taking this on.

Because I think it's critical to understand both the origins of the safety goals as well as where they should go.

I'd like to make a couple of comments regarding our views on the use of the current safety goals in Part 53. What I haven't heard here is one issue that concerns me. And that's the safety goals, at least combined with current understanding of the relationship between large releases and total number of cancer deaths, really corresponds to core damage frequencies on the order of one times ten to the minus to the third, one times ten to the minus three.

And that's obviously considerably lower than what the fleet average CDX is considered these days. So the safety goals are no longer, they don't represent a standard of safety that's anywhere near what the current fleet is supposed to represent. And therefore, they set too low a bar for establishing fundamental safety limits going forward.

And this isn't an issue of whether the NRC should ratchet up safety goals for new reactors or not, this is simply recognizing what the current situation is and the safety goals in relation to them. So if you keep this, you know, the safety goal limit as, you know, this very low bar, it's just not very useful in establishing important safety goals for the future. So I think that has to be recognized.

Another issue, another deficiency with the safety goals is this averaging over, you know, the general U.S. population, you know, general just averaging over individuals in specific reactor sites. These types of averages wash out the kind of disproportionate impacts of a nuclear accident and how it could affect vulnerable populations differently.

And it's also -- so in addition to the heterogeneity of, you know, the U.S. population in so many different ways, also the use of cancer fatalities instead of cancer incidents doesn't acknowledge or it's not sensitive to the disparities in care that lead to different cancer mortality risks for different populations compared to incidents.

And so continuity is -- cancer mortality in averaging is not recognizing the important disparities that, I think, the NRC, as well as the whole of the federal government, are trying to address now for the link into their varying environmental justice initiatives.

So I think those are some of the highlights in addition to, of course, the lack of the societal safety goal which, I think, the committee understands very well and should definitely be a part of any future regulatory regime that's incorporating safety goals. Because that's a gap which should be apparent to anyone. Those are my remarks. Thank you.

CHAIR BIER: Thank you very much. Any other public remarks? If you are on Teams, you can raise your hand to be recognized. If not, feel free to just unmute yourself and speak up.

Dave, are you --

DR. JOHNSON: I was muted, sorry. Let me say, I think Ed's got some great points. And I wasn't trying to have a comprehensive view of where we should go in the future or all of the sins we've had in the past. Yet somewhere along the line we, the industry and the NRC, you know, moved away from Level 3 studies. And I think some of those issues would be more visible if we had more Level 3 studies and looked at some of the issues you talked about.

There's a number of things you'll run across when you're going back through the NRC presentations and documents on some metrics. You know, for example, in several places I have found words that said that core damage frequency is a surrogate for society cancer risk. And that's, of course, nonsense. I mean, it might be necessary, but it's not sufficient. We're fooling ourselves if we think that that's a decent surrogate measure.

So I think, when you think this problem through and you're in the group, you have a chance of doing a much better job than when we did back then. We're older and wiser, and it's a more complex landscape. So anyway, that's my two cents.

CHAIR BIER: Thank you. Again, opening up for any other public comments. We have another 30 seconds or so.

Okay. Hearing none, I think we can go back to general committee discussion at this time. And I will just add that, if anybody is listening in, feel free to send your remarks to Hossein after the meeting is done.

Walt?

MEMBER KIRCHNER: Well, thank you very much, Dave, for your presentation, very informative. I previously had highlighted the metric that was used in one of your slides which were essentially, how do I phrase this, instead of, it was like a surrogate for a reactor year, assuming that the reactor was nominally 1,000 megawatt class.

So it raises the question going forward about reactor year, as per year, reactor years as a metric if we proliferate a lot of small reactors over the countryside. I don't mean that as a pejorative statement, but it certainly -- how do you actually then measure the impact? Do you do it on an individual reactor or some cumulative effect, societal effect. So I'm not looking for an answer, just make that an observation.

The second one, maybe I would pose this one more as a question. How, as we go forward and if we base the licensing approach more and more on a PRA, how do we go back and address the QA issue that you talked about of, well, now we currently have standards and reg guides for this purpose. And then we use peer review. But it's not necessarily the equivalent of the deterministic world in NQA 1.

So do you have any feelings on that? How do we go forward? Because one of the concerns would be with, especially new designs, what are the unknowns out there? And how do we thoroughly search the space to hopefully make sure we're comprehensive in covering the landscape of potential risk to the public from a new concept?

And you have a good example. If you're stripping fission products actively, then you're creating, you know, a source term, so to speak, that's potentially at risk of, or vulnerable is a better word to use here, of release. Any thoughts on what we could do? Or do you think the current process for peer review meets the mark in terms of QA of the PRA?

DR. JOHNSON: Vicki, can I speak --

CHAIR BIER: Oh, yes, you should feel free to reply.

DR. JOHNSON: So I have the ability to alienate any number of people, ha. I think the QA for the PRA as specified, or as followed in the standards, is excellent. The weakest point in that process by far is the peer review requirement. It's kind of done quickly at the end.

It's highly, and this is my opinion, it's highly dependent on the team that you put together. I can show you -- maybe that's too strong a statement, but I'm aware of one element of one PRA that was, and appropriately exactly the same set of words from a different PRA. One got a best practice, and one got, you know, unacceptable.

You know, there was a time when PRAs were sent to a national lab, and they spent gobs of money, but you came back with an SER, right, that had some value to it.

I think if we were to utilize PRA more, we would need to go back and think about that peer review process and current resolution process coming out of that. I think that's the, probably the only weak point there.

The other point to mention is that these new technologies are going to be exploring new physics, right, with different materials and things like that. That has to be represented in the studies. And that can be in terms of performance, and safety, et cetera.

And I guess the last point I wanted to make is you said something about PRA-based licensing. I think that's the last thing that we're asking for. Because exactly, there are things that PRA is not appropriate or doesn't handle well. And that's the whole idea behind the performance based ideas is there will be a set of deterministic criteria blended with risk requirements and risk measurements. So I'm optimistic.

But I think we do need to change how we do the QA part of the, the peer review part of the PRA and get people to really understand what PRA is. I'm pessimistic that somehow that's been lost.

CHAIR BIER: Dave, one minor point of order. I think we are looking at your security cam footage. So you might want to stop sharing your screen or something. Looks attractive, but not necessarily what you want to be sharing.

MEMBER KIRCHNER: It's my yard.

CHAIR BIER: Yeah. Okay.

(Simultaneous speaking.)

CHAIR BIER: Let me see if I -- maybe I'll try to undo it.

(Simultaneous speaking.)

CHAIR BIER: Thomas, is that something you can do on your end to take down his screen sharing or do something?

PARTICIPANT: Hold on a second. Stop sharing.

CHAIR BIER: Awesome, excellent. Much better. Thank you.

Vesna, you can go ahead now.

MEMBER DIMITRIJEVIC: All right, as long as I find my microphone. Yeah. Hi, David. So I can be very vocal against what they're proposing currently in terms of part 53 in the PRA-based approach.

And what they're proposing to use is a realistic safety goal which is based on the latter and the early fatalities. So basically what they're proposing to use is a goal, the individual within ten months, or client, is exposed to loss and fatality base less than two to the minus six period.

And I'm very vocal against this. There is a couple things why I am very vocal, and you just said this in one of your last sentences. And what you said is to the CDF, is using CDF as substitute of the goal for the counter fatality is really, you know, ludicrous in my opinion. And I have a feeling you have the same opinion.

So I have often expressed this. I've wrote additional opinion, but I cannot find a really good argument, because the main argument NRC has against that is that served them well, you know, through the years. So my argument will soon develop, but in the PRA is subsidiary goal, CDF and Murph but not the cancer goals and not only fatality goals.

So in my opinion, you know, the qualitative goals are, you know, not to present additionally to the society. That took time. I thought that we have enough problem with going one percent, you know, that that's enough, a significant addition.

So this project that they are promoting is also, you know, okay to say it's a goal. But transferring, having the goal for the new plant to be built to prove that a loss in fatality risk or cancer risk is less than three minus six per year, that's total nonsense in my opinion. It's nonsense mostly because when we say two minus six, it implies that we know something about that.

So that could be it's not three minus six, it's not 40 minus six, it's two minus six. And that will imply that we totally understand connection in this case. And I'm just going stay on core damage frequency, so it's totally agreeable in discussion as to the early fatalities.

So that means that we totally understand connection between, you know, core damage frequency and cancer, and that we, you know, it neglects all the uncertainties which are totally widespread everywhere, you know. There is uncertainties in Level 1, there is the higher certainties in Level 2. And when we come to the Level 3 uncertainties, in my opinion, are really high.

And also there is, you know, when they completed this PRA Level 3, the project in NRC that have shown in the Level 3 which they have done, that actually connections between the core damage frequencies and the, you know, cancer risk, or the early fatalities is much smaller than they would estimate based on the early PRA. So currently probably core damage frequency of ten to minus two would satisfy this goal for cancer.

So my objection is totally to remove the cancer and the early fatalities as probabilistic goal. But however, I don't really have a good idea of what could replace that. And I was thinking we can really work with whoever comes in the first application with the people trying to estimate risk connected.

If there is no core damage frequency, and there is no large release frequency, if there is a core damage frequency, large release frequency, stay on the current goal.

If there is some, then let's work together to develop some new representation of the societal risk. So basically what I wanted to say, my main objection is to use the cancer and early fatalities as probabilistic safety goal in this moment. So I don't know what your opinion about something like this would be.

DR. JOHNSON: So I guess my first reaction is go back to the Level 3 PRAs that were done in the, you know, late '70s or early '80s. I think they would all say that there's not a strong connection between core damage frequency and offsite health effects. The scenarios that contribute to offsite health effects tend to be smaller in frequency.

But I have to say that, you know, NRC's reason for existing is to protect the public health and safety. So I think they have to have public health and safety measures as part of their goals, et cetera. And I don't, you know, I agree with you that the scenarios are few and far between. But I guess, where do I start?

It has frustrated me that, with the utilities I've work with, there's been a couple who understand that the real scenarios that they need to guard against aren't limited to the ones that result in maybe core damage frequency at all.

But, you know, there are scenarios that would result in their loss of plant with the fuels intact. And, you know, they spent money to avoid, you know, that sort of thing. So I'd be happy if utilities adopted a holistic view of safety. I'd be happy if the NRC adopted a view that focused on public health and safety.

I still don't understand why we stopped doing Level 3 studies. The one NRC did, it doesn't have to be as complicated as what they did. So I don't know. I'm frustrated. What can I say?

But I guess I would like to leave with one question, is what is it they share as, what's their charter, if you will? What's their goal for providing input on a quantitative study, quantitative health study, or quantitative risk goals, if you will?

Back in 1980, it was to try to get NRC to think about if framework for how they do business, not particularly establishing rules and goals for individual plants. That would fall out of the analysis. But it was to try get NRC to quit being kind of ad hoc, if you will.

MEMBER DIMITRIJEVIC: Well, you know that everything started, you know, with the WASH-1400 core damage frequency and large release frequency. And they were --

DR. JOHNSON: Well, I --

(Simultaneous speaking.)

DR. JOHNSON: -- release frequency. They had release categories. My release frequency --

MEMBER DIMITRIJEVIC: Right.

DR. JOHNSON: -- is something that --

(Simultaneous speaking.)

DR. JOHNSON: -- essentially was admitted later that has really muddied the water. Go ahead, excuse me.

MEMBER DIMITRIJEVIC: Well, then in the time which you just described working with, you know, existing Zion and the point -- whatever existing PRAs at that time, it was proved that this core damage frequency, so ten to minus four and whatever, large release, or ten to minus five, really don't introduce large additional cancer risk and prompt fatality risk to the public.

So it started from the CPS and the releases. And then we went to prove that it didn't increase risk to the public. But now that risk to the public drives, you know, it's a sort of, now it's a sort of back to that chicken and egg. Now the risk for public becomes the prompt driver. And there are so many implicities associated with that.

So when I was thinking working with whoever is the first one to pass who doesn't have a core damage frequency, and it could be different releases, it could be different damage to the core. It focused on different measure which will be presented and still guarantees there is no increase in the risk to the public. I mean, you know, I'm not sure. I think we have to wait instead of presenting this cancer and early fatalities risk to --

DR. JOHNSON: I hear what you're saying.

But, you know, just the window, WASH-1400 also included land contamination. It's just that somewhere along the long we stopped talking about that. And that's probably the biggest signature that the public would see.

MEMBER DIMITRIJEVIC: What was it did you say? I didn't hear you well.

DR. JOHNSON: Oh, WASH-1400 also included a measure of land contamination.

MEMBER DIMITRIJEVIC: Yeah, right. No. You know, when you were building all of these in the '80s, we didn't have a Three Mile Island, we didn't have a Chernobyl, and we didn't have a Fukushima.

We can look back now and learn much more, you know, what are really consequences of the nuclear accidents and how we can measure them instead of, you know, trying to state for something which was developed 40 years ago. So, I mean, that's my, you know, but thanks for these questions.

CHAIR BIER: Yeah. Joy?

MEMBER REMPE: I'd like to respond to Dave's question about what our charter is and our task. Because I even see in some of Dave's slides that question could easily get -- the answer might be incorrect.

And what you said at the very beginning of this meeting is correct, Vicki, that we have a working group, and we are exploring what might be improved. Maybe it's just an implementation of the safety goals, but we do not have a charter to investigate this task.

We saw there were difficulties when we were reviewing Part 53. And you mentioned in your presentation, Dave, how much more difficult it is with some of these reactors that have molten fuel, for example. And we're just gathering information, as Vicki said, at this time.

And so again, when we have a working group in ACRS, it's to help us look at something that we think might be important to safety. But we don't have a clearly defined charter at this time. Does that help with responding to your question, Dave?

DR. JOHNSON: Yes.

MEMBER REMPE: And I'm making a big point of this because the public is also listening to it.

CHAIR BIER: Sure, yeah.

MEMBER REMPE: And I want to make sure that no one walks away from this meeting with an incorrect assumption, if possible --

(Simultaneous speaking.)

CHAIR BIER: Yes. I mean, first of all,

we have not been tasked by the Commission and the staff to look at safety goals, and we have not determined that we are going to propose any modifications or whatever.

But it did come up as part of our Part 53 review, which is supposed to be technologically inclusive regulation framework, that some of these technologies would not fit comfortably into the established safety goal framework. So we wanted to just think through the implications of that.

So I have a few questions for Dave, but I should wait and see if any other committee members have additional questions right now.

Okay, I will charge ahead then. First of all, the most closely tied in a way to the Part 53 analysis, as you indicated Part 53 allows multiple different frameworks including possibly bounding analysis that a plant might come in without a PRA and just say, hey, we have this calculation that says our risk is less than such and such.

So your argument that, well, it should be possible to do simplified PRA for simplified reactor designs, even if we think that's a good thing, that should be assailed at least in terms of what's permissible under Part 53 that somebody would not need to do that.

And do you have any thoughts about what you might recommend or consider if plants do come in with a bounding analysis? If their bounding analysis is satisfactory, does that mean they already might have safety goals, or is there some other safety goal type check that could be imposed?

DR. JOHNSON: I don't know if that's an answerable question. My reaction is that, you know, one lesson that we should have learned over and over again, and we don't seem to, is whenever we try to simplify PRA, or bounding analysis, et cetera, the day will come when we realize that that was an error.

CHAIR BIER: Ha, ha, ha.

DR. JOHNSON: So if the ship has sailed, the ship has sailed.

CHAIR BIER: Yeah.

DR. JOHNSON: If they come in with a bounding analysis, I would put my hat on and try to show why it's not bounding. That's a tough thing to do, right.

CHAIR BIER: Yeah.

DR. JOHNSON: You know, like I said, a simple plant could have an elegantly beautiful but simple PRA, and you'd embrace it.

CHAIR BIER: Okay. Two other points, one which isn't really a question but really just an observation that I think you really helped clarify, I have commented in the past that the comparison that's in the goals with baseload coal plants may not apply very much anymore if the majority of baseload power in many parts of the country is no longer coal.

But you raised this other point that everything has gotten safer --

DR. JOHNSON: Right.

CHAIR BIER: -- since then. Coal plants are safer, because they have more scrubbers. Cars are safer, because we have anti-lock braking systems and all kinds of other things.

And so, you know, maybe the era where we were replacing dirty coal plants with cleaner, nuclear plants, that kind of comparison might have made sense, but in a world where everything is already safer, maybe we don't need to be safer than everything else that's out there, kind of.

DR. JOHNSON: I don't want to, yeah, move away from the idea of comparison directly. I mean, you can even talk about green technologies.

CHAIR BIER: Yes.

DR. JOHNSON: Some of them look nice on

the future and nice in our backyard but, you know, there's a very coherent argument that says what we've done is we've exported our pollution.

CHAIR BIER: Right. If you take a complete life cycle view, they're not all that green necessarily.

DR. JOHNSON: So I wouldn't jump on that boat.

CHAIR BIER: Okay.

(Simultaneous speaking.)

CHAIR BIER: Right. The one other comment I wanted to make, that ties a little bit to the point you raised about security risk and physical sight security, my understanding is that initially part of the reason that was taken out of PRA, or not included in PRA is maybe a better a way of putting it, is just that it required different expertise and different precautions. And in particular, you might require a security clearance to --

DR. JOHNSON: Right.

CHAIR BIER: -- do the work or access the results so it didn't fit in a public document like a PRA.

But one person I've talked to recently raised an interesting point that if you are looking at plants where the inventory and the source term are small, and therefore the risk is extremely small, sabotage and, you know, physical security might be the single biggest source of risk.

You know, yesterday we saw an analysis that had extremely low risk numbers for technology. And, you know, the probability of a successful sabotage event might be higher than the risk numbers they cited using their traditional PRA approach.

DR. JOHNSON: So the security questions, your last question is probably the old argument for keeping the security scenarios closely held.

CHAIR BIER: Yes.

DR. JOHNSON: But, you know, since 9/11 we no longer make FSARs and PRAs that are --

(Simultaneous speaking.)

DR. JOHNSON: -- publicly. Because, you know, one of them gave you the layout drawings, and the other one gave you the --

(Simultaneous speaking.)

CHAIR BIER: Yeah.

DR. JOHNSON: -- summation of effects. But there is a new reg that I've used, and I'll try to dig it up. The text itself is kind of worthless, but there is an appendix that helps you characterize external threats, if you will, in a spectrum that's a function of what their goals are, what their technical expertise is, what tools they have available, what price they are willing to pay.

And it goes from petty theft type things, to news of shutdowns of the plant, all the way up to the core damage frequency. So I've used that spectrum to look at security risk stuff.

And with a different hat, I've been looking at the barriers to reintroducing nuclear to commercial shipping, et cetera, et cetera. And at least we're on that now. My thinking is we can make the reactor -- very robust to external bad guys, et cetera, et cetera.

But the success from the bad guys' point of view may not be dispersal of power. It might be sinking that ship that has a big N on the side of it. I mean, you need to think broadly of what success and failures are in these cases.

CHAIR BIER: Yes.

DR. JOHNSON: But I honestly think that we need to step back and look at this whole security question from a holistic point of view and not isolate it the way it is now. But I should say, I think I'm the only one saying that.

(Laughter.)

CHAIR BIER: Well, I think I'm --

MR. MEIER: I don't think so, Dave. I've heard other people --

MEMBER KIRCHNER: Yeah, I think you're right on, Dave.

MR. MEIER: -- express that exact comment. Yeah, I know people working actively in this area, they kind of push back.

MEMBER KIRCHNER: Yeah. So far, Dave --

CHAIR BIER: At a minimum --

MEMBER KIRCHNER: -- it doesn't serve the public's good.

CHAIR BIER: Yeah.

MEMBER KIRCHNER: On this particular issue as impacts safety and potential risk. So I think you're right on, Dave. Yeah.

CHAIR BIER: And at a minimum, you know, our whole approach in this current working group is to say, hey, maybe we don't need to be bound by the assumptions of several decades ago we could take a new look, and see if we have more sensible assumptions. And so security might be one area where we may want to do that.

So any other questions or comments for

Dave?

Well, this was extremely interesting. I think it gave us a lot of good things to think about. And I want to thank everyone also for their comment.

And, Dave, I will be getting back to you probably in the next few days just to help track down a couple of references that we may want to add to our database to be informed by.

DR. JOHNSON: Okay. I have a limited number that I kept during the --

CHAIR BIER: Yeah.

DR. JOHNSON: --- and brought in.

CHAIR BIER: Well, that's okay. I understand it's a long time ago. You probably purged a lot of paper. So, you know, and some -- Hossein and the staff may also be able to track down at the NRC. But for instance, the Bowen reference that you mentioned seems to be cited but not easily available online from what I can tell. So, you know, we may need some effort to track that down through a library or something.

DR. JOHNSON: And then Paul Slovak has got a wide collection of, you know, publications he may have at his plant.

CHAIR BIER: Yeah, for sure. Okay.

DR. JOHNSON: All right. I'll go eat lunch now.

CHAIR BIER: Good, fantastic. Well, thank you very much for joining us. And I guess I will see everybody in a couple of weeks at full committee.

MEMBER REMPE: Thanks, Vicki and Dave.

CHAIR BIER: Sure thing. Thank you.

(Whereupon, the above-entitled matter went off the record at 2:51 p.m.)

A Perspective on Nuclear Quantitative Safety Goals

David H. Johnson, ScD
Las Cruces, New Mexico

Presentation Outline

- Introduction
- 1980 ACRS Safety Goals
- Safety Goals developed for 1998 HIFAR PSA
- NRC QROs
- Moving forward in an era of SMRs and Microreactors

1980 ACRS Quantitative Safety Goals

- Historical Environment
  - Limited number of nuclear PRAs
    - 1975 WASH 1400 Final Report
    - 1978 Oyster Creek PSA
    - 1979-1981 Zion and Indian Point PSAs
  - Attitude at NRC regarding PRA mixed
  - TMI was a recent event
- Inconsistent Federal Guidelines
  - Radiation exposure limits
  - Delaney Clause of Federal Food, Drug and Cosmetic Act (Food Additives Amendment of 1958)

ACRS Quantitative Safety Goals Published as NUREG-0739

NUREG-0739

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An Approach to Quantitative Safety
Goals for Nuclear Power Plants

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Manuscript Completed: October 1980
Date Published: October 1980
Advisory Committae on Reactor Safeguards U.S. Nuclear
Regulatory Commission

Key contributors: M. Griesmeyer, D. Johnson, W. Kastenberg, D. Okrent

ACRS Perspective on Importance of Safety Goals

"…NRC Rules and Regulations … and in NRC Staff documents dealing with safety … such as Regulatory Guides and Branch Technical Positions…(represent) basically a risk reduction philosophy without fully articulated safety goals."

NUREG-0737, Page 51

Safety goals key to providing NRC with a coherent framework for effective regulation

Goals were not to be considered absolute or viewed in isolation – there may be excellent reasons to allow operation above goal

Form of the Quantitative Decision Rules

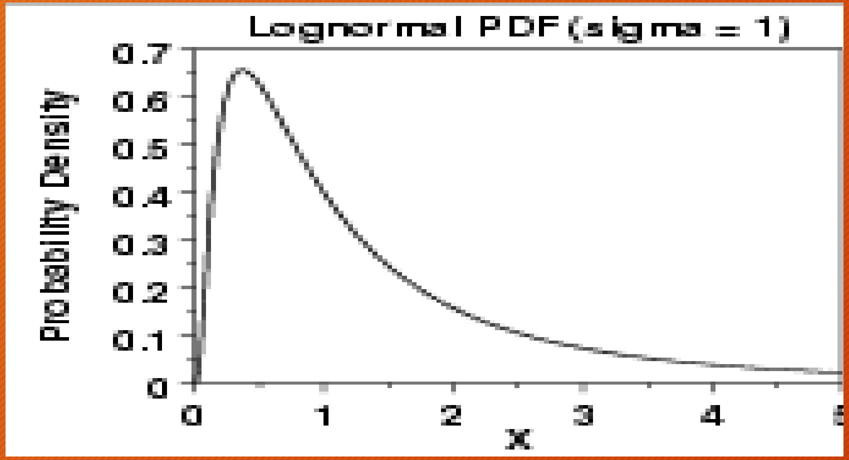
- Limits on the frequency of certain hazards states within the reactor
- Limits on the risk to an individual of early death, or delayed death due to cancer
- Limits on the overall societal risk of early or delayed death (includes a small measure of risk aversion)
- ALARA
  - Includes Averted Negative Economic Impact/Loss of Resources

Assumed that controlling early deaths and latent cancer deaths would control other effects as well

References

- Adams and Stone: 1967 risk to an individual should be governing factor; specific value responsibility of appropriate government body; limit should be smaller than the demographic variation in the UK of individual's risk of dying from other hazard sources; something on the order of 10^{-5}.
- Farmer: 1967 0.01 premature deaths per ry. In addition, a frequency-consequence due to I^{131}. Included risk adversion.
- Bowen: 1975 Risks should be smaller than benefits gained by technology
- The Committee benefited from meetings with Bill Lowrance and Paul Slavic

Different Metrics Were Explored



One of my (rejected) ideas.

Why do we do PRA?

1. Arrive at a rank ordered list of scenarios that contribute to specific damage states
2. Identify and understand sources of uncertainty

To approach the second goal: establish goal/limits on 50th and 85th, rank order contributors

The best cdf curve we had access to was an early draft of Zion PSA. 50th percentile was 1×10^{-4}; 85th percentile was 5×10^{-4}. (You will see these numbers again soon.)

Goals and Upper Limits for Hazard States

Significant core damage (10% Nobles leaking into primary coolant)	Goal: Less than 1/100 per reactor lifetime	Goal: Less than 3 x 10^{-4} per ry	Limit: Less than 1 x 10^{-3} per ry
Large Scale Fuel Damage	Goal: Less than 1/300 per reactor lifetime	Goal: Less than 1 x 10^{-4} per ry	Limit: Less than 5 x 10^{-4} per ry
Large Scale Release from Containment (greater than 10% I and 90% Nobles)	Goal: Small, given Large Scale Fuel Damage	Goal: Less than 0.01 per LSFD	Limit: Less than 0.1 per LSFD

Upper "Nonacceptance" Limit; a Discretionary Range ; and a Goal

Numbers look familiar?

Compliance with Upper Limit Required for Extended Operation

Individual Risks (Most Exposed Individual)

Likelihood of cancer death due to all reactors at site over individual's lifetime: less than 0.0005	Goal: less than 5×10^{-6} per site year	Limit: less than 2.5×10^{-5} per site year	Goal: Mean conditional likelihood given LSFD: less than 0.01	Limit: Mean conditional likelihood given LSFD: less than 0.05
Likelihood of early death due to reactor accident over individual's lifetime: less than 0.0001	Goal: less than 1×10^{-6} per site year	Limit: less than 5×10^{-6} per site year	Goal: Mean conditional likelihood given LSFD: less than 0.002	Limit: Mean conditional likelihood given LSFD: less than 0.01

Background cancer death risk 0.15 – 0.20

In the US, 10-14 year-old girls have lowest death rate 10^{-4}

Societal Risks

Expected value cancer deaths- normal operation and accidents	Goal: less than 2 per 10^{10} kwh (approximately 1200 MWe at full capacity)	Limit: less than 10 per 10^{10} kwh
Expected value early deaths due to accidents (alpha=1.2)	Goal: less than 0.4 per 10^{10} kwh	Limit: less than 2 per 10^{10} kwh

Estimates available in 1980 suggest similar size coal plant results in 10-200 excess delayed deaths

Additional Requirements

- Special attention should be given to QA of PRA
- Full and explicit identification of assumptions and limitations
- Peer review required

- Additional suggestion: Establish a Risk Certification Panel with statutory authority

Hindsight

- Only Individual risk of cancer death explicitly considered all reactors at a given site
- While Zion PSA was full scope, level 3; role of shutdown risk not appreciated
- Co-located technologies not considered
- Whereas Coal risk provided a benchmark for some measures, nuclear replacing existing technology not considered

- I still believe we missed the chance to provide appropriate attention to uncertainty

High Flux Australian Reactor (HIFAR)

- DIDO Class research reactor: neutron diffraction, transmutation of silicon and medical and industrial isotope production
- 10 MW-th, heavy water cooled, moderated; graphite reflected
- HEU (changing to LEU 2006)
- Operational 1960 to 2007
- PSA (and companion probabilistic remaining life study): 1998
- Level 1+ PSA

References

- OECD: 1994 fuel damage 10^{-4} to 10^{-5}
- Netherlands: 10^{-4} for existing plants, 10^{-5} for new plants
- In the US, as of November 1995, 14 of 77 plants reported a cdf greater than the informal limit 10^{-4}.
- HIFR reactor at ORNL: 3×10^{-4} cdf

- Difficulty in comparing above due to varying scope, methods

References: New South Wales Department of Planning

- Maximum incremental annual risk of premature death

Hospitals, schools, child care facilities, old age housing	0.5×10^{-6}
Residential developments and areas of continuous occupancy	1.0×10^{-6}
Commercial developments	5.0×10^{-6}
Sporting complexes and active open space areas	10×10^{-6}
Industrial sites	50×10^{-6}

Key Point: Australia had a framework relating activities to risk

Objectives versus Limits

Relevant Factoids

Relatively modest power: 10 MWth
Low primary system pressure
Limited supporting analyses for mechanical damage
Limited supporting analyses for recriticality
Limited analyses for transport of Tritium

- Primary Objectives: fuel overheating
  - Fuel in core or number 1 storage block: $5x10^{-4}$
    - Some existing NPPs exceed $1X10^{-4}$
    - Thermal power 10MW vs 2000-3000MW
    - HIFAR slightly above atmospheric vs 75-160 bar
  - Fuel in core or number 1 storage block with containment failure due to bypass, failure to isolate or overpressure: $5x10^{-5}$
- Secondary Objectives:
  - Mechanical damage to one or more elements (with and without containment)
  - Fuel element mechanical damage resulting in overheating or criticality
  - Loss of cooling to stored fuel
  - Release of tritium without fuel damage (with and without containment)

Key Point: Objectives were specified on fuel damage frequency and unanalyzed events

NRC Safety Goals

- Qualitative
  - Individual members of public bear no significant additional risk to life and health
  - Societal risks to life and health should be comparable to or less than the risks of generating electricity by viable comparable means AND should not be a significant addition to other societal risks
- Quantitative
  - Individul risk of prompt fatalities should not exceed one-tenth of one percent of the sum of prompt fatality from other accidents to which public is generally exposed
  - In are near a nuclear plant, cancer risk due to plant operation should not exceed one-tenth of one percent of cancer fatalities from all other causes
- Additional views of Commissioner Asselstine: Commission should have developed policy on the relative emphasis of accident prevention and accident mitigation (to provide balance between the two)

Moving Forward - Challenges

- Spectrum on new technologies (or rediscovery of old technologies) on the horizon
- Spectrum of reactor sizes; operating pressures
- Multiple reactors at sites
- Mobile reactors
- Our experience with LWRs has created bias (e.g., what does Level 1 mean for MSR or He cooled reactor?)
- How to treat co-located technology?
  - Beneficial
  - Harmful

More Considerations

- Does nuclear facility get “credit” for replacing existing technology?
  - Coal plant replacement
  - Diesel
  - ANSWER: NO, but risk from replaced technology provides a reference point
- How are 10CFR73 (or 10CFR53.860) scenarios to be considered?
- Why are Industry and NRC avoiding use of PRA?
  - Some in industry reluctant to use PRA in design, it seems
  - A simple design should imply a simple PRA (e.g. HPRR PRA was some 50 pages)
  - Option B of part 53 seems to specify unphysical scenarios (‘maximum’ accident not possible EVERY year)

1980 vs 2023 Your Task in More Challenging

	1980	2023
Reactor Designs	Only PWRs and BWRs (we ignored Ft St Vrain)	Diverse Designs
Power Levels	‘large’	Diverse, many quite small
Siting	Fixed terrestrial	Diverse including mobile and marine
Key Pressure	1000-2200 psi	Diverse including near atmospheric
Fuel Type	Metal clad ceramic	Various: molten salt, Triso, etc
Coolant	Light water	Various
Industrial Application	Primarily electrical generation	Diverse including syn fuel/industrial
Security Considered	No	Yes?
Fission Products well characterized	Yes	?
Neutron Spectrum	Thermal	Diverse