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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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648TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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OPEN SESSION

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THURSDAY

NOVEMBER 2, 2017

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ROCKVILLE, MARYLAND

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 8:30 a.m., Dennis C. Bley, Chairman, presiding.

COMMITTEE MEMBERS:

DENNIS C. BLEY, Chairman

MICHAEL L. CORRADINI, Vice Chairman

PETER RICCARDELLA, Member-at-Large

RONALD G. BALLINGER, Member

CHARLES H. BROWN, JR., Member

WALTER L. KIRCHNER, Member

JOSE MARCH-LEUBA, Member

DANA A. POWERS, Member

HAROLD B. RAY, Member

JOY L. REMPE, Member

JOHN W. STETKAR, Member

MATTHEW W. SUNSERI, Member

DESIGNATED FEDERAL OFFICIAL:

KATHY WEAVER

HOSSEIN NOURBAKHSH

ALSO PRESENT:

ALEXANDER ADAMS, NRR

MICHAEL BALAZIK, NRR

KEITH COMPTON, RES

MICHAEL CORUM, Northwest Medical Isotopes

GARY DUNFORD, Northwest Medical Isotopes

HOSSEIN ESMAILI, RES

TINA GHOSH, RES

CAROLYN HAASS, Northwest Medical Isotopes

STEVE LYNCH, NRR

TYRONE NAQUIN, NMSS

MARY JANE ROSS-LEE, NRR

PATRICIA SANTIAGO, RES

RUTH THOMAS, Public Participant*

ANDREA D. VEIL, Executive Director, ACRS

*Present via telephone

T-A-B-L-E O-F C-O-N-T-E-N-T-S

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

8:30 a.m.

CHAIRMAN BLEY: The meeting will now come to order. This is the first day of the 648th meeting of the Advisory Committee on Reactor Safeguards.

During today's meeting the Committee will consider first Northwest Medical Isotopes Moly-99 Radiation Production Facility. Second, preparation of ACRS reports, and third the state-of-the-art reactor consequence analysis, SOARCA for Sequoyah.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act. As such, this meeting is being conducted in accordance with the provisions of FACA. That means that the Committee can only speak through its published letter reports. We hold meetings to gather information to support our deliberations.

Interested parties who wish to provide comments can contact our offices requesting time after the *Federal Register* notice describing the meeting is published. That said, we also set aside 10 minutes for spur-of-the-moment comments from members of the public attending or listening to our meetings. Written comments are also welcome.

Ms. Kathy Weaver is the designated federal official for the initial portion of this meeting.

Portions of these sessions on Northwest Medical Isotopes may be closed in order to discuss and protect information designated as proprietary. If so, we'll do that at the end of the session.

The ACRS section of the U.S. NRC public web site provides our charter, bylaws, letter reports and full transcripts of Full and Subcommittee meetings including the slides presented at the meetings.

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

There will be a -- there is a telephone bridge line. To preclude interruptions of the meeting the phone will be placed in the listen-in-only mode during presentations and Committee discussions.

Today there is also a web cast. Often the sound is better there than it is on the line, but you would not have the opportunity to make comments at the end unless you're on the phone line. Also, for the last two days there have been agency-wide problems with the web cast, so it might drop off on you. If so, you can come back in on the bridge line.

A transcript of portions of the meeting is being kept and it is requested that the speakers use one of the microphones, identify themselves and speak with sufficient clarity and volume so that they can be readily heard for our transcript.

As an item of interest today we would like to announce and congratulate Dr. Steven Schultz, current consultant and former ACRS member, for being elected as a fellow of the American Nuclear Society. Wish Steve were here, but we send our congratulations to him.

At this time I will turn the meeting over to Dr. Powers for the discussion of the moly-99 facility.

MEMBER POWERS: Good morning. I'm Dana Powers, a very poor substitute for the ever-lovely Margaret Chu, who is actually the chairman of this Subcommittee. She alas is basking on the beaches of Taiwan while the rest of us fever away.

We're going to discuss a construction permit application for Northwest Medical Isotopes for a radioisotope production facility. All nuclear facilities of course are unique. This is no different. It has its own peculiarities.

Margaret has proved to be a vicious task master and we've had some intensive Subcommittee meetings beginning in June, July, August, September.

And then she gave us a break in October. So today we're here to get a summary, a vast amount of information. So at best we're going to get a synoptic summary of the facility and construction permit reviews.

We're going to hear both from the applicant and from the staff on this. I'm sure that the applicant will devote their time to a description of how they conceive this nuclear facility, and I will hope that the staff describes how they organized and conducted their review of this construction permit application.

Our intention today is to have a non-proprietary discussion. Should things come up that are proprietary, somebody will have to signal me; I'm not good at identifying things that are proprietary, and we will defer that discussion to the end of the meeting when we can close the session.

Without any additional to do, I'll ask Mary Jane Ross-Lee to open the discussion on this particular construction permit application.

MS. ROSS-LEE: Thank you, Dr. Powers. As you mentioned, my name is Mary Jane Ross-Lee. I am the new deputy director of the new Division of Licensing Projects in Office of Nuclear Reactor

Regulation. This is my first week on the job, so I -- though ironically I was a branch chief when the moly facilities first came about in their licensing process back many years, so I do have a little bit of a history in this.

Our staff in NRR and in the Office of Nuclear Materials Safety and Safeguards are pleased to be here today to brief the ACRS Full Committee on the staff's review of the construction permit application for the proposed Northwest Medical Isotopes production facility. With that being said, this work has been conducted by a large interagency group. The main contributors were NRR, NMSS, Office of Nuclear Security and Incident Response, Office of the General Counsel and Office of Congressional Affairs.

As was mentioned, the staff has conducted five ACRS Subcommittee meetings on the Northwest Medical Isotopes construction permit application, having met with ACRS members each month this summer. The staff also conducted a technology briefing of the Full Committee back in May of this year. We appreciate your time and the priority you have given to this important project.

I don't need to discuss the importance of having a domestic supplier of this essential radioisotope as I'm sure all members are aware.

Your insights on the safe operation, the design of the nuclear facility and the use of nuclear materials has been benefitted the staff's review and better informed our finding supporting the issuance of a construction permit to Northwest Medical Isotopes. In addition to the NRC staff that is here today, Carolyn Haass and Mike Corum for the Northwest Medical Isotopes are here to present information on their application. They will begin the discussion going through their presentation on the application, and then the staff will present on the licensing process and where we're at on that following that.

So with that I'll turn the presentation over to Carolyn Haass.

MS. HAASS: Hi there. I think the majority of everyone was on the Subcommittee except I think for Peter and Michael. I know that you guys were here in the May time frame when we gave the overview. So today I'm going to do a quick overview of our facility and then we're going to go into what the changes of our construction permit application were based on the ACRS review. And obviously everyone has changes, and we wanted to go over those one more time with you.

Next page. So I think everyone's aware what our business model is, is that we're going to go design, construct, and operate a radioisotope production facility of which you see that in the circle where it says processing facility. In the process of that we're also going to have a captive network of universities' research reactors that are going to support us with irradiation of our targets. And the reason we're going to have a network of them is so we can have the reliability and assurance of the moly supply to the radiopharmaceutical companies, which then go to the end user.

We are looking at multiple shipments per week, and that is based upon what the radiopharmaceutical companies request. They usually request that they have a delivery like on Monday, Tuesday, Wednesday and Friday. And so --

MEMBER POWERS: When --

MS. HAASS: I have no --

MEMBER POWERS: -- fascinated what happens on Thursday.

MS. HAASS: I have no idea. They've never really told me that one, but that's what they do.

(Laughter.)

MS. HAASS: From an RPF -- from the

radioisotope production facility perspective we have two primary activities that we do under the Part 50 licensing of which -- why we were here, and one would be for the moly production and the second one is for uranium recycle and recovery. There will be a Part 70 portion of this facility, which is target fabrication, and that will be in -- because it was not considered as part of this construction application, it will be considered -- we'll be submitting that with our operating license application when we do the Part 50 side.

Next slide. So I think everyone's aware, you know, we have our unit reactor network and that our facility is going to be located in Columbia, Missouri. It's going to be about six miles from our primary reactor, which is the University of Missouri Research Reactor. We're also about five miles from the regional airport there. We have a second reactor identified, which is Oregon State University. And then we have a third reactor which we have not signed on the dotted line. We have it, but it's very, very similar to the OSU reactor.

Next. So our -- where we're going to be located in Columbia, Missouri, as I said, it's about six miles away from the University of Missouri

Research Reactor. It is on university-owned land. It is in the Discovery Ridge Research Park. And our lot is about 7.4 acres. It contains no existing structures. It was -- this land was actually donated to the university system when -- a family donated it when someone passed away. And it was all agricultural land it had been used for agriculture for over 100 years.

Also the research park is being developed under the master plan protective covenants that the University of Missouri has developed.

VICE CHAIRMAN CORRADINI: Just for clarification --

MS. HAASS: Yes.

VICE CHAIRMAN CORRADINI: -- where is the research reactor in comparison to this? Just so I understand.

MS. HAASS: I don't have that picture here.

VICE CHAIRMAN CORRADINI: Can you just kind of point?

MS. HAASS: Well, so this here, this is just the research park itself.

VICE CHAIRMAN CORRADINI: You can point with the mouse.

MS. HAASS: Oh, sorry. This is just the research park itself, the 550 acres.

VICE CHAIRMAN CORRADINI: Oh.

MS. HAASS: The research reactor is about six miles over here.

VICE CHAIRMAN CORRADINI: Oh, okay. Thank you.

MS. HAASS: Yes. So what you do is you go down Highway 63 for a bit, and if you know anything about their reactor, you go down and into Providence, but --

VICE CHAIRMAN CORRADINI: That's fine. Thank you.

MS. HAASS: Sure.

The primary assumptions for our radioisotope production facility is we're going to have one single facility. And as I stated earlier, the facility is going to have two primary items under the Part 50 licensing, which is moly production and uranium recycle and recovery. We'll also be doing target fabrication.

Our moly production is based on a fission-based method. It's kind of what everyone uses in the world now. I know that there's other technologies that they're trying to develop, but we believe we're going to be using the gold standard. We're also going to be using low-enriched uranium for our moly production. Our nominal capacity is about 3,500 six-day curies, and we have a surge capacity. Just in case some other facility worldwide came down, we would have the capability of producing more.

I think I've gone over the network university reactors, but two key things there is the target design is the same for all reactors. We understand power influx can be different, but we've gone through all the calculations, whether you're a 1, 5 or a 10-megawatt reactor. Also we do have intellectual property and we've been going through the IP process, you know, or the patents for that. And you can see where -- who's allowed. Some are still pending, but we're in the process. We'll be -- probably in the next three to four months we should have everything sewn up on that one, which is great.

This NRC licensing strategy page, page 6, talks about the different activities in a little more detail. What's going to be under Part 50. What's under Part 70. And then obviously you're going to have a Part 30 byproduct material handling portion of the license.

The other key thing here is each

university will have to do a license amendment to be able to irradiate our targets from a commercial perspective. They will be submitting their license applications separately. It will come through them with our support. Also there is one cask that we will have to go and evaluate and see if we have to have a license amendment because of a heat load. And that would be to transport the irradiated targets from the university back to the radioisotope production facility.

So what this diagram shows is we have four primary things that we do in this production facility: target fabrication, irradiated target disassembly and dissolution, then the moly production, and then the uranium recycle and recovery. The one item you see where the picture is, you see a picture of the University of Missouri research reactor here. That is the one item that we don't do in our facility is irradiate targets. That's all I was really trying to say on this. I think you guys are very familiar with this.

The facility description. It's about a 52,000 square foot main floor, square foot facility. There is a basement, and that is where your hot cell -- your tank hot cell is, where all your critically safe tanks are. That's also where we're going to be storing our high-integrity containers for decay prior to disposal at the appropriate disposal facility.

We also have a second floor, a mezzanine, and if I would talk to it, that's where we'll have our utilities, ventilation and our off-gas system. And, no, I don't think I need to talk about the rest. Cute little picture. You keep seeing the same one over and over.

Project schedule. We haven't talked about this a whole lot, but our goal is to start site preparation/construction in the second quarter of 2018. We want to end construction about 15 months later. We want to start cold commissioning in mid-2019 with hot commissioning towards the end of 2019 and the first quarter of 2020. And then obviously you've got to go through your FDA runs, but that doesn't -- that's not shown here, but that's after you get through your hot commissioning. And the reason I had the date of decommissioning, because it was one of the requirements that we had to put in the application. So it's around 2050.

So now I'm going to get to the meat of the presentation, and I know that most of you are aware of this, but we're going to go through what the major changes were based on your input and comments.

And from chapter 2 I will say thank you again, John, for all your help. And we went and modified this. And what I did is I just listed the items. We've been through this in detail, but we modified transient population and the nearby industrial transportation, military facility, accident scenarios, the airports and heliports. We reevaluated the pipelines, the highways and the other nearby facilities for explosions and things like that. And we are working in -- we're finalizing all of that, so it will be in the operating license application.

MEMBER STETKAR: So I just want to clarify, Carolyn --

MS. HAASS: Oh, yes.

MEMBER STETKAR: -- you're going to carry those forward to the operating license?

MS. HAASS: All of this gets carried for.

MEMBER STETKAR: Yes, okay.

MS. HAASS: Anything that we have here or anything that we have stated we will be putting in the operating license application is carried forward.

MEMBER STETKAR: Okay. Because the kind of protracted discussions that we had during the Subcommittee meetings were focused primarily on the justification for summarily screening out those hazards, which means they would not have been reexamined during the operating license --

(Simultaneous speaking.)

MS. HAASS: Correct.

MEMBER STETKAR: I understand that you are going to carry those forward.

MS. HAASS: Yes, we have actually completed a lot of those reexaminations. We did resubmit chapter 2. Yes, you find another mistake in there. And they've gone back and they have redone those calculations that we will be resubmitting in the operating license.

MEMBER STETKAR: Okay. Thank you.

MS. HAASS: So, but there's a whole list of things here in chapter 2. I don't need to read this for you, but we updated some of the historical data that was in there that you requested. So we did that. Also one of the things that you guys asked about several times was our design evolution, and I just wanted to say our design is being completed in stages. We have completed our preliminary design. We're on our final design, and that final design is required for our -- the operating license application submission and to complete our construction drawings. And we understand how important it is to get this operating license in as soon as possible because we want to start getting the staff to start reviewing that. But obviously we couldn't get it in before we had approval here.

So after you do the final design, as I stated above, we start going into our construction drawings and specifications. And then there's a whole bunch of supporting documentation that is going to be finalized, and then a lot of this will go into the operating license application such as the final hazards analysis, the final CSEs and associated calculations. And it's everything we've talked about, but with the final design this will all be updated. I don't want anyone to think that we're going to leave it at a preliminary state, because every bit of this is so important to our final design. We understand how important fire is and criticality and emergency preparedness and waste management, and those things will be completed.

CHAIRMAN BLEY: Carolyn, just a --

MS. HAASS: Yes?

CHAIRMAN BLEY: -- point of information for the record. The Committee hasn't requested that you do anything. We only speak through our letters.

MS. HAASS: Right.

CHAIRMAN BLEY: Some members pointed out --

MS. HAASS: I apologize.

CHAIRMAN BLEY: -- things they saw as problems or missing information in your application. And that's why we went after it.

MS. HAASS: You've had wonderful suggestions.

MEMBER POWERS: Flattery, yes, it helps, but not a lot.

MS. HAASS: Okay.

(Laughter.)

MS. HAASS: Okay. But we know to be able to submit an operating license application all these items have to be final. They are only in preliminary and they will be updated.

So page 12. I'm going to hand this over to Mike.

MR. CORUM: Okay. In chapter 2 and chapter 3, that's where we get into seismic. And Northwest Medical Isotopes is going to use the response, seismic response spectrum from Reg. Guide 1.6 with -- anchored in ground acceleration, peak ground acceleration of 0.2 g. And we've compared that to the GMRS that was established through the PSHA that the staff, the NRC staff did on reviewing the Missouri research reactor submission.

And we found that the GMRS is enveloped by the Reg. Guide 1.6 seismic spectrum up to about 16 hertz. Based on EPRI guidance we know that anything above 10 hertz in frequency is not going to damage the structural components of the facility. We will pay particular attention to the functional performance of components that are sensitive to vibration and we will evaluate those. If we have to seismically isolate them, we will. And that will all be part of our final design going forward in the operating license application.

MEMBER POWERS: Mike, just an item of curiosity. You've anchored 0.2 g, and the way it's stated up there you anchored it based on looking at Calloway and MURR.

MR. CORUM: Correct.

MEMBER POWERS: Did you do a trade study at all on what it cost you to go to construction at 0.3 g versus 0.2 g?

MR. CORUM: We have not fully evaluated that at this point.

MEMBER POWERS: Just an item of curiosity in your opinion. Nothing further.

MR. CORUM: Okay. Continuing on in chapter 3, the tornado missiles, that will be part of our natural phenomena hazards analysis that we will complete during final design. And I think that's really all we need to say here.

On chapter 5, the coolant systems, things that we've added, the weekly irradiated target heat generation rate we added. The thermal load we characterized by the radial heat transfer in a vessel and the uranium concentration of the solutions that are held within the vessels throughout the RPF. And we'll also add the number of targets to be irradiated, basically optimize those in the operating license application.

Moving onto chapter 6, the criticality accident alarm system. We will design that system to meet 10 CFR 70.24. We're going to commit to the current endorsed version of the ANSI/ANS-8.3 with the modifications that are noted in Reg. Guide 3.71. So we'll be using a slightly different source term based on Reg. Guide 3.71 versus 8.3.

We'll complete the evaluation during the final design. We'll also be working with a vendor that will supply the system to us during that final design phase. And we are not going to take exception to any shielding in the hot cells. We are going to provide the CAAS system in those areas for evacuation purposes for personnel in the facility. And we will make sure that the emergency power that's provided to the system is going to be from a UPS.

From a criticality safety standpoint prior to the end of construction and before the operating license application we'll to make sure that all processes that contain SNM are evaluated to be subcritical under all normal and credible abnormal conditions. We'll specifically control the parameters: mass, geometry, moderation, volume and interaction, and we will commit to controlling those parameters at the safety limits and evaluate the parameters that are not controlled at their most reactive credible values.

We do acknowledge that if we use a single NCS control to maintain control over two or more control parameters, that that is only one constituent to meet the double contingency principle.

Order of preference for our controls, as we've always had, is passive engineered or passive design features followed by active, then enhanced administrative and finally simple administrative. And one other point that if we do use two or more controls on a single parameter we'll commit to using diverse rather than redundant means of control.

Consistent with our revised validation, we'll make sure that we contain SNM under normal credible abnormal conditions to meet the revised USL 0.924. The criticality safety evaluations will be updated during the RPF final design to reflect this. We've completed the criticality safety calculations already to show that all of our processes will remain below 0.924. We do have to formalize those and document them, but we have finished that part of the study. And I think that's -- I think we've said everything else that we needed to say about that one.

On chapter 7, the instrumentation and control systems, we'll make sure that the IROFS, the ESP safety functions are activated via hardwire interlocks and operate independent of the normal control system. The process control system will include interlocks that implement an automatic action on a parameter approaching or being outside of its setting, and we'll also implement a permissive philosophy that will allow operations to be enabled once the control room has confirmed prerequisite conditions have been completed for certain activities.

MEMBER POWERS: So your operating philosophy is you request the control room, tell them what you're going to do. They check the permit, the conditions. And then you get permission to do it?

MR. CORUM: Correct. Yes.

MEMBER POWERS: And that's a feasibility simply because of the simplicity of the general system?

MR. CORUM: It is, yes.

MEMBER POWERS: It's somewhat cumbersome.

MR. CORUM: It would be in I guess a more complicated process, or layout.

MEMBER POWERS: Well, just a --

MR. CORUM: Yes.

MEMBER POWERS: More people running around asking things?

MR. CORUM: Exactly.

MEMBER POWERS: But basically you'll have one or two people perhaps asking for permission at any given stage in the operation?

MR. CORUM: Correct.

MEMBER POWERS: So you're just taking advantage of the simplicity of the system?

MR. CORUM: Yes, sir.

Okay. Then chapter 13, uranium metal

fires. We do know that we're going to be fabricating the targets from uranium metal. Basically we've evaluated this a little bit, but we've got more evaluation to come.

MEMBER POWERS: Well, you're really not fabricating targets from uranium metal. You're just --

MS. HAASS: Broken metal.

MEMBER POWERS: -- dissolving it and then --

MR. CORUM: Yes, it's part -- yes, it's broken metal that comes in and --

MEMBER POWERS: And so you just have a transient period where you're handling it?

MR. CORUM: Correct. Correct.

MEMBER POWERS: It's not like you're making a metal fuel or something like that.

MR. CORUM: That's correct. That's correct, yes.

MEMBER POWERS: So I mean, this is -- and this is fairly episodic. I mean, it's not every day.

MR. CORUM: Not every -- it's not an everyday occurrence, but we do have to be prepared for it. We acknowledge that.

MEMBER POWERS: Well, it makes it a rare

evolution inside there. It requires some special attention.

MR. CORUM: Sure. Sure. And as part of our final design we plan to implement the appropriate controls in the areas where we're going to be handling this material and have available material that could extinguish a U metal fire such as magnesium oxide sand. It may be something else.

MEMBER POWERS: Yes, magnesium oxide I'm not fantastic about --

MR. CORUM: Yes.

MEMBER POWERS: -- because of the worst furnace fire I ever had was heating magnesium oxide because it involves oxygen at elevated temperatures and --

MR. CORUM: Very much.

MEMBER POWERS: -- not what you want around a reacting metal.

MR. CORUM: No, not what you want in a fire.

MEMBER POWERS: But there are materials to handle it. The real hazard here is not the fire per se. It's the aerosol production --

MR. CORUM: It's the off-gas, yes.

MEMBER POWERS: -- that you get. And

trust me, having burned my share of uranium metal those aerosols are absolutely nefarious in their ability to get into places you don't want them.

MR. CORUM: Absolutely.

MS. HAASS: And based on the questions that we have gotten over the last four or five months from the Committee, we have gone and done a trade study. Obviously it will be part of our operating license, but it will -- it's very specific T metal fires. And we'll be incorporating that into chapter 13.

MEMBER POWERS: Yes, that's fine. That's good. I mean, it's -- these metal fires have had occasions when it's radioactive metal of shutting down facilities for a very long time because they're hard to clean up.

MS. HAASS: Right, and definitely it's not really suppressing the fire. It is the off-gas or the aerosols that come off the fire --

MEMBER POWERS: That is your hazard.

MS. HAASS: -- that become the issue. We completely agree.

MEMBER POWERS: Yes, quite right.

MR. CORUM: And that completes our presentation, if there's any questions.

MS. HAASS: Yes, sorry it was short and sweet, but I know everyone probably here has heard and seen this many times. And that's why we were just going to open it up for questions.

MEMBER POWERS: I think you've covered what's expected. I mean, the essential point is that we need to understand conceptually. You're required to demonstrate a knowledge of the hazards here. I think that did it quite well. Thank you very much.

MEMBER STETKAR: Mike?

MEMBER POWERS: Do any members have additional questions they'd like to pose?

MEMBER STETKAR: Yes.

MEMBER POWERS: You're shaking your head.

(Laughter.)

MEMBER STETKAR: I'll be gentle.

Mike, during your discussion about IROFS you mentioned that your intent is to provide diverse rather than redundant IROFS, which is a good idea. We had during the Subcommittee meetings some discussions about your integrated safety assessment where you evaluate the benefit that you achieve from each of the IROFS. And in particular we had some discussions about the use of administrative controls: personnel monitoring, personnel activities and so forth.

In several of those instances in the ISA there is; and I have to be careful here, credit taken for redundant personnel activities. Those are not particularly diverse necessarily.

MR. CORUM: No.

MEMBER STETKAR: So and I know the ISA is an evolving, kind of living sort of analysis, but do you have any comments on the area of administrative controls versus hardware-based things --

MR. CORUM: Right.

MEMBER STETKAR: -- without getting into details.

MR. CORUM: Our philosophy going into the final design is we're going to try to eliminate where possible as many of the administrative controls that we can and replace that with -- hopefully with -- well, primarily with passive design --

MEMBER STETKAR: Yes.

MR. CORUM: -- and try to get away from that. With any handling operation in these types of facilities you're going to inevitably have to have some kind of administrative controls, but we certainly aren't going to use the same operator or the same I guess requirement and call that double contingency.

Two operators looking at something and say that's doubly contingent. That's not going to happen in the final design.

MEMBER STETKAR: Thanks. We look forward in the final design to see how you handled that.

MS. HAASS: We look forward to you reviewing.

(Laughter.)

MEMBER POWERS: Any other questions of the applicant?

(No audible response.)

MEMBER POWERS: Now we'll turn to the staff and they can explain to us how they went about reviewing this construction permit application.

And, Mike, we're particularly interested in areas where you felt it necessary to do independent investigations, calculations, analyses, audits and things like that and where you've relied on particularly Mr. Adams' vast experience with these facilities to identify areas of focus. But the floor is yours.

MR. BALAZIK: Thank you. So I'd like to start by just making a couple high-level comments about what we're going to be talking about.

First, happy to be here and --

MEMBER POWERS: That's the first lie.

(Laughter.)

VICE CHAIRMAN CORRADINI: But he has vast experience.

MR. ADAMS: Happy to be here. And in this area I'm wondering where my vast experience is.

So we're going to focus on talking about the review process, the how we did it and why we've done it the way we did, because there's not a lot of recent examples of construction permit reviews outside of what we did for SHINE. And it is different. It's different than an operating license review. It's different than a combined license review. And I think those differences are important to understand because they guided us with what we looked at, how we looked at it. And so we're going to try to clarify what's different between an operating license and a construction permit.

We're going to tell you about the construction permit conditions. Those are probably the most important conditions that came out of our review because we're recommended to the Commission that they make it part of the license.

As we talked about looking forward, we'll be back with the operating license review. We plan to approach that as -- it's a different review. The yardsticks are different. The regulatory requirements are different. Obviously informed by what we've done here from the design philosophy and the basis, but it's a different review. However, it will be informed by the commitments that we are keeping track of that were part of this review.

If you look at Appendix A of our SER, you'll see two sets of commitments, and one set was based on RAI answers that Northwest gave us. Northwest said, well, this is something that we'll talk about more in the operating license or an issue that will close out the operating license. We noted it and listed it down. Also in that appendix is issues that came up during the Subcommittee meetings. And so those commitments are also listed and as reminder to the staff as they go through the operating license to make sure that each one of those are checked off.

MEMBER POWERS: To me the hardest step in doing this construction permit is the acceptance criteria. There's always a tendency to get -- to ask for more and more detail and more specificity and things like that. And that kind of qualitative sense of where they've met the actual requirement even though there's residual uncertainty. It's not quite clear exactly how it will be done.

MR. ADAMS: Right, and that's the biggest challenge is where do you draw that line? We are -- we've gained some experience doing that because this is the second time we've done it, but it's based a lot on the judgment of the staff. Also guided by the regulations. The regulations tell us what the applicant needs to give us. For example, measurements don't need to be exact. They could be in the ballpark. So we try to be guided by the regulations.

But you're right, there's always -- there's a tendency to keep wanting to go down the path, wanting to know -- wanting to have knowledge, wanting to have those details. And we have to stop ourselves and remind ourselves that this is a construction permit. We're not making any safety findings here. We're not making -- we're not approving this -- we're not approving any aspects of the safety of this facility.

What we're doing is we're saying that there's enough preliminary information that the applicant has thought about what they're doing, that they've covered it from a design philosophy, a design basis, that they are thinking along the right lines and there's enough there to allow -- to say to them, okay, go ahead and start construction.

During construction we have a Construction Inspection Program that will watch carefully what is being down like with the application of their QA Program. And of course the operating license is where the rubber meets the road and all the loose ends are tied together.

So the applicant does understand that they move forward with some level risk on these issues that are commitments or taking a philosophy or licensing basis and turning it into how thick a wall is or how many -- or what the pipes look like. They understand that clearly and we understand that, too, which is why we're looking forward and why we'll be back.

MR. BALAZIK: This is Mike Balazik, Dr. Powers. Also just within our guidance, NUREG-1537 and the Interim Staff Guidance, the review of each chapter took a look at the acceptance criteria. And if they could say that, yes, Northwest met that acceptance criteria, we documented that in the SER.

Now of course, all the acceptance criteria aren't met, but if with the information that we had we looked at that to see if we could meet it and come to a finding.

MEMBER POWERS: Yes, it just strikes as thinking about putting myself in your shoes that it would be a continual reminder of where I've got cut things off in here. I mean, it would be a struggle. I mean, I don't envy your job here.

MR. BALAZIK: Yes, sir. And like I said, our technical reviewers, in some cases they had to use engineering judgment --

MEMBER POWERS: Sure.

MR. BALAZIK: -- to make that determination.

MEMBER POWERS: Yes.

MR. ADAMS: And like I say, this is the second time we've done this, so we are gaining some -- we did gain some lessons learned from the first time we'd done it.

Given our limited time there's a lot of technical things we could have talked about. We're going to focus on one of those and tell you how we followed up on the -- in the area of aircraft impact, because that was an area where we did have a lot of discussion and we did get a lot of help from the Subcommittee.

CHAIRMAN BLEY: Al, before you go forward with that, I agree this is a tough piece you've been doing, but I wonder, it's been a long time since we did these. We're just doing our second. There's been a longer time since we went from construction permit to an operating license, and maybe the answer to my next question is hidden and we didn't make any safety findings. But how are you going to ensure when you get to the operating license that we don't carry over our biases from this review, because we've made findings based on somewhat incomplete information and I think the temptation would be to say, oh, I kind of closed that issue before. I don't need to dig into that very hard this time around.

MR. ADAMS: And you're right. That is a very important aspect and that's why we are going to approach the operating license from sort of a clean sheet of paper. It's a different yardstick. And so we can be informed from the construction permit in that, yes, there is philosophies and design bases that were discussed in the construction permit and we're going to see those were carried forward into the operating license. But one important thing is that things that -- that very little is closed at this point, that we come back and we take a fresh look because it's a different yardstick.

MEMBER POWERS: Very different from an

earlier site permit --

MR. ADAMS: Yes, it's a different yardstick.

MEMBER POWERS: -- where we're not closing anything out.

MR. ADAMS: Yes. Different yardstick and a different set of conclusions we need to reach. So I mean, that's the answer.

MR. LYNCH: Yes, the staff also recognizes that there is a potential for the design of the facility to change substantially between the issuance of the construction permit and when we receive the operating license, and that's to a certain extent expected as the design evolves.

One of the ways we'll address that as we get to the operating license application is -- our expectation is we will continue to have preapplication meetings going into the operating license application and during construction where Northwest will highlight some of the significant design changes so the staff, when we get the operating license application, has a good understanding going into that review what has changed from our previous review and we'll be informing that review somewhat from those commitments that were made.

MR. ADAMS: And one thing we did was the development of a non-power and production facility Construction Inspection Program that -- the program that existed was very old. Last time it was exercised was in the early 80s at the University of Texas. So given all the insights and everything we've learned since then, we made the decision to write a completely new program. And the Office of New Reactors took the lead for that along with the folks down in Region II and the construction inspection folks. And so that is another important part to making sure at the end where we need to be.

To issue an operating license, there are a lot of things we need to look at, but one of them is that the Construction Program determines that the facility was built as described in the FSAR. So that's a very important yardstick, that what was reviewed, what the Committee is going to look at also is what is sitting there.

So with that I'll -- any other initial questions? If not, I'll turn it over to Mike.

MR. BALAZIK: Thank you, Al. I'll go ahead and start the presentation. First of all, just a quick overview of Northwest Medical Isotopes' application. Submitted a Part 50 construction permit application for a production facility for the following activities: disassemble and dissolve the low-enriched uranium targets; recover and purify molybdenum-99; and recover and recycle uranium.

It was a two-part construction permit. The environmental report was docketed in May of 2015 and the preliminary safety analysis report, otherwise known as the PSAR, was docketed in December of 2015.

Also; and I know this has been the discussion of a lot of Subcommittee discussions about the target fabrication, I just wanted to put out that we expect a Part 70 application for the possession and use of special nuclear material to be submitted in the future. And this facility, as Northwest stated earlier, is going to be constructed in Columbia, Missouri.

MEMBER STETKAR: Mike?

MR. BALAZIK: Yes, sir.

MEMBER STETKAR: You brought it up, and we had -- we did have some discussions about this. And how does the staff -- because there will be a Part 50 license and there will be a Part 70, and yet it's a facility that lives under the same roof and is operated by the same people, has common what I'll call support systems: cooling water ventilation, electric power, AC/DC, all that kind of stuff. How does the staff treat in the final reviews the integrated safety assessment, because the integrated safety assessment can't be a distinct Part 50 separate from the Part 70 integrated safety assessment because then it's not integrated. So how does the staff -- how do you do that in your reviews?

MR. BALAZIK: Well, I think that would be a --

MEMBER STETKAR: Because this is unique.

(Laughter.)

MR. BALAZIK: No, no. No, sir, I totally agree it's unique. And just from the standpoint of the construction permit we kind of looked --

MEMBER STETKAR: Not -- I'm not talking about a construction permit. I'm asking you looking forward --

MR. BALAZIK: I understand.

MEMBER STETKAR: -- because we haven't seen any of the -- we, the ACRS Subcommittee at least, hasn't seen any of the Part 70 licensing information, if you will.

MR. BALAZIK: Correct.

MEMBER STETKAR: So I'm asking you going forward, because we're talking about how you're going to accomplish this task.

MR. BALAZIK: Correct. So --

MEMBER STETKAR: How do you that?

MR. LYNCH: So our -- so one thing, based on what Northwest has told us, they are intending to submit a single application at the operating license stage that will cover the Part 50 operations and the Part 70 operations. So during our review we will have an opportunity to look at how those two areas: the target fabrication area and the hot cell processing area interrelate. So our expectation is that we will be conducting essentially a single review of all of those operations within the facility to understand how they interact with each other. So it will be everything under a single roof evaluated together under that ISA.

MR. ADAMS: And I think you've seen an indication of the -- how we look at the interaction and that the accident scenarios that were looked at. One of them was is there something that the target fabrication area could do that would impact the production facility? So that -- we're already starting down that path, but --

MR. BALAZIK: And, Member Stetkar, just one more item to add to this is for this review we've used NMSS significantly. So these are the same reviewers that are going to be looking at the Part 70, and that benefits us significantly in this type of review.

MEMBER STETKAR: Okay. Good. Thanks. But again, we kind of look forward to see how you work all that out.

MR. BALAZIK: Yes, sir.

So on slide 4 the Northwest facility includes several hot cell structures which meets the requirement, or the definition I should say, of a production facility. A production facility is defined as any facility designed for processing of irradiated materials containing special nuclear material. And there's also a threshold for that, so if the material processed in batches is greater than 100 grams of uranium-235, it's a production facility.

So while the NRC has historically licensed Part 50 production facilities, no such facility is currently operating. We did issue a construction permit for SHINE in early 2016. And we also had a Part 50 license for West Valley, which was reprocessing fuel. I think that was back in the '60s time frame.

MR. ADAMS: In the '60s. And there was

domestic production of moly-99 in the United States of cintycam in New York. It was not a production facility because of that 100-gram discussion in the definition. Their batches are less than 100 grams, so actually the area where the moly and the uranium were separated was done under a Part 70 license. So the technology here, the chemistry here is actually long-established and similar to what's used throughout the world for the production of fission product moly-99.

MR. BALAZIK: Okay. So this next slide, slide 5, I kind of wanted to touch on the scope of the review. Even though there was a lot of information in the application, some of this information we didn't consider for our findings for the production facility. So the radioisotope production facility has a production facility which we're reviewing now and a target fabrication area.

So for target fabrication it's the processing of un-irradiated uranium that does not meet the definition of either a utilization facility or a production facility. So these processes and hazards associated with this target fabrication are more like fuel cycle. So Northwest, they'll need a license for receipt and possession of fresh LEU. It will be greater than a critical mass. And they'll also be doing scrap recovery of special nuclear material.

And in the PSAR it states that the target fabrication will be -- the license will be applied for under a separate Part 70 license application.

So when the staff --

MEMBER KIRCHNER: Just for the record when do you expect that application?

MR. BALAZIK: Well, as Mr. Lynch mentioned earlier, right now we expect that application with the operating license. And Northwest can correct me, we expect that in the second quarter of 2018. I mean, that's what they had on the board earlier, too. But there's nothing that prevents them from submitting them separately.

So in the staff's review of testifying SSCs they weren't considered unless they were shared with a production facility. No safety findings were made on their adequacy for the target fabrication. And what Northwest pointed out earlier is that these targets identical are going out to research reactors. So each research reactor would have to submit a license amendment before they could irradiate these targets.

CHAIRMAN BLEY: And I'll add we have not seen any of those amendment applications as of today.

MR. BALAZIK: So big picture on the scope of the review. The SER findings are limited to the Part 50 production facility.

Regulatory Guidance. I'll just touch on this real quick. I know that we presented this a lot during the Subcommittee meetings, but the primary guidance that the staff used was NUREG-1537, which is preparing and reviewing applications for non-power reactors. But once we -- I should say early on the staff developed generator because we saw all kind of gaps in the NUREG-1537 on production facilities.

So we came up with the Interim Staff Guidance that kind of addresses the production facility -- licensing of production facilities. And a lot of that information that we incorporated came from NUREG-1520, which is the Standard Review Plan for a fuel cycle facility. And there's also a lot of other guidance that the staff used. For example, ANSI Standard 15.8, which is quality assurance, and 15.16, which is EP for RTRs.

These are the areas that the staff presented on. Well, we didn't present on all of them, but we presented on chapters 1 through 9 and 11 through 13. These were all discussions during the Subcommittee meetings.

Just wanted to touch on some of the construction permit requirements. I would say some of the more important ones are 50.34 on what is needed for a preliminary safety analysis report; in other words, what does Northwest to include? Also, the occupational dose limits and public dose limits in 10 CFR 20. And also for what findings the staff needs to make in order to issue a construction permit in 50.35. And we'll talk about that a little bit later. And we'll also touch upon 50.40 and 50.50.

Just a note here. In the ISG, in the guidance it states that the staff has accepted 70.61 for performance requirements, that it may be used to demonstrate adequate safety of a medical isotope production facility. And that's what Northwest has done. So that's kind of unique and I think that's maybe one of the first times that we've actually used an ISA methodology for a Part 50 facility.

MR. LYNCH: There's a -- and real quick, one thing I want to highlight in terms of our -- that may be unique in terms of our review of the consequences of this facility to the public. Using the Part 20 occupational and public dose limits, we're also using that public dose limit of up to 500 millirem as an accident criteria, which is more conservative than is typically used for power reactors under Part 100.

MR. BALAZIK: And just to continue on, also I just want to point out a couple regulations that --

MEMBER POWERS: Well, it's not at all surprising that you would use a more conservative criterion, because you don't meet all the other requirements.

MR. LYNCH: Well, I will -- part of this is the absence of accident dose criteria for non-power production and utilization facilities. The staff is addressing this separately as a rulemaking. We do have a proposed rule that will set an accident dose criteria of one rem for these facilities. And we're moving forward on that. We expect the final rule to be published and implemented by 2019 or 2020.

MR. ADAMS: But you're right, Dr. Powers, that all of the additional siting requirements that come with Part 100 are not applicable to this facility.

MEMBER POWERS: So I mean --

MR. ADAMS: So it's logical that the doses would not be the same, that --

(Simultaneous speaking.)

MEMBER POWERS: Yes, it's not at all surprising. You picked one that's good enough for --

MR. BALAZIK: Just a quick note on the bottom two bullets. There are a number of regulations that don't apply to the Northwest facility. One of those is the -- or one of the more significant ones is the General Design Criteria of Appendix A, but Northwest is still required to have a General Design Criteria in accordance with 50.34. Also Appendix B, quality assurance, doesn't apply.

As I mentioned earlier, the staff's review consisted of the ANSI Standard 15.8. And also Part 100 also doesn't apply. And what the staff did is within NUREG-1537 there's specific criteria for site characteristics that we use that's equivalent to the Part 100.

MEMBER POWERS: Well, parallel perhaps.

MR. BALAZIK: Yes, I'd say parallel, not equivalent. If it was equivalent, then I guess they would use it.

MR. ADAMS: But the same concepts are there. We looked at meteorology, we looked at weather, we looked at seismology, we looked at the dirt, we looked at the rocks. So the same -- it's a parallel. It's the same waterfront, so to speak, but the purpose is a little bit different than -- well, is different than Part 100.

MR. BALAZIK: Just real quick I'll touch on the construction permit application contents. The PSAR needs to include a preliminary design of the facility, principal design criteria, design bases and approximate dimensions, a preliminary analysis of structures, systems and components including the ability to prevent and mitigate accidents, probably subjects of tech specs, preliminary emergency opinion, a Quality Assurance Program, and research and development.

And I just want to kind of contrast that the operating license which Northwest -- when they submit that, it will be the final safety analysis. And also they'll supplement the environmental report if needed. And what they need to include in the operating license is the emergency plan, tech specs, physical security plans and plans for operation.

MR. ADAMS: Can I step back a second? So this is the heart of the difference between a construction permit and an operating license is those words on the last slide: preliminary design, preliminary analysis, probable subjects of tech specs, preliminary emergency plan. A Quality Assurance

Program, because that is so important to make sure the facility is constructed property. That's one that's not preliminary. And research and development. Again, you'll find in Appendix A there is a list of -- there are some issues that are still research and development issues for Northwest, and those issues need to be brought to a satisfactory close that the staff will accept before the operating license is granted.

MR. BALAZIK: I think Al may have covered most of this, so we'll skip it unless there's any questions. It just talks about a construction permit versus an operating license.

So I just want to touch on the NRC review methodology. The construction permit only allows construction. The level of detail in the application, the staff's SER is different than what you would see for a combined license or an operating license application.

For issuing a construction permit, the facility may be adequately described at a functional or a conceptual level in the PSAR. And I think form the Subcommittee meetings we've seen that. For example, chapter 7 was more of a conceptual or functional level, which we didn't really have a lot of details.

Northwest has deferred providing many design and analysis details until the submission of its final analysis report with its operating license application. And the staff review was tailored to unique and novel technology described in Northwest's construction permit application using appropriate regulatory guidance.

And for that last bullet I can just say that's the whole Part 70/Part 50 piece that we talked about earlier.

MR. LYNCH: A lot of our review methodology too was to make sure that we understood that the applicant had an appreciation for where are they going when the operating license application is submitted. So we may have requested additional information from the applicant with respect to holes we identified in the application or we found that acceptable responses were -- the applicant understood that this is something they needed to do later, but didn't have the information now so that we had that information docketed that they understood the full scope of what was to come. And that's part of what we based our conclusions on is did the applicant understand what the -- where they needed to get for the final design and how to path forward to getting there.

CHAIRMAN BLEY: I think in the next few slides you have a place to answer this question, but maybe an overview answer at this point would be helpful. When you reviewed the safety analysis section, what were you really looking for there? Were you looking for completeness? Were you looking for their knowledge of how to carry out those kind of analyses? What were you looking for in the safety analysis?

MR. ADAMS: Well, I think some of it was just looking at their methodology to make sure that they were using the correct guidance, the correct standards, looking at some of their inputs and ensuring that -- well, I guess --

MR. LYNCH: Some of it will depend on the chapter. For example, chapter 2 when we're looking at siting requirements, that's an example --

CHAIRMAN BLEY: The chapter on safety analysis is the chapter I asked about.

MR. LYNCH: Sure. With the safety analysis that was more methodology that we wanted. Have they identified initiating events? Did they look at the different types of accidents that could occur at the facility?

CHAIRMAN BLEY: Were you interested in the completeness in their look for initiating events or just that they --

(Simultaneous speaking.)

MR. LYNCH: We were looking for what we call a vertical slice or a cross-section. Do they have a representative example of the different types of initiating events? In terms of the completeness of those events, that's something we'll look at when the full ISA is submitted with the operating license application. But, yes, the focus for the preliminary safety analysis report in the accident analysis section was the methodology to make sure that they gave the staff confidence that they were technically qualified to carry out the full review at the operating license stage.

MR. ADAMS: And that's an area where we did look -- we did take a slice and look at what they were doing in detail for that slice. And it's an area where for example the application did not talk about some aspects of chemical hazards and the staff independently calculated for example over-pressures of detonations within hot cells to satisfy ourselves that we were in the right place as far as the designs of the SSCs go.

MEMBER KIRCHNER: Do you do an independent analysis on the source terms that kind of bound the applicant in some bounding analyses? Do you do an independent check on that, because that basically is what's used to say they can meet the siting requirements with regard to radiation exposure and such?

MR. LYNCH: Sure, we have done some limited evaluation of this and at the construction permit stage I would characterize that as more qualitative. What we did look at were the applicant's ability to define their safety-related SSCs, the IROFS to establish that methodology for putting these controls on different processes within the facility that would be within a certain bound.

And right now Northwest in their application has stated that under accident conditions they're intending to meet the 10 CFR Part 20 limits of 500 millirem for those accidents with the engineered and administrative controls placed on them. So once we get to the operating license application review, we will be looking at these accidents with that in mind.

MR. ADAMS: But that was an area where we did have a discussion with the applicant to understand that they clearly define the basis for the source term, because there was some question. Was it eight MURR targets? Thirty Oregon State targets? What type of decay did those targets receive before they were handled in the facility? If you look, you'll see there was RAIs in that area and discussion of what appeared to be some inconsistencies across the application. So that's one thing we do at that stage was to make sure that there was a clear basis for a source term that we understood and found to be agreeable.

MR. BALAZIK: So in the staff's review of the PSAR and resolving technical deficiencies there was a couple options. Staff determined that such technical issues must be resolved prior to issuance of a construction permit. And also there are other items that can be left until submission of the operating license or the FSAR. And also that they required technical issues be resolved prior to completion of construction, but after the issuance of a construction permit.

So in all these cases staff asked a considerable amount of RAIs, but in the second and third options a lot of these are tracked as commitments or identified as licensing conditions.

And we'll talk about those a little bit later.

So let's talk about --

MEMBER POWERS: How do you -- I mean, you've got three options that you lay out there. Is it largely engineering judgment on those or --

MR. BALAZIK: It is. I'd say it's part of it, but also the reviewers wanted to look at or ask the question what do they think would actually impact construction of this facility? What may make them have to pour concrete or stuff like that? Larger items, not -- I would say that is more of the view on looking at that.

MEMBER POWERS: It really boils down to if I got a -- if I'm going to have to chip out or pour concrete to correct something here, then it better be part -- it better be resolved now. If I'm not going to have to do that now, I got two options.

MR. BALAZIK: Yes, that's a good characterization.

MR. ADAMS: That's a good characterization. It's engineering judgment, but also applying that engineering judgment to the particular yardstick for construction permits, which we talked about. You know, preliminary, preliminary, preliminary.

Sometimes that first option of asking an RAI, again it was to make sure there was a complete understanding. It would be a case where, geez, they didn't say much of anything about this and we'd ask an RAI. And then they could come back and say, yes, we're aware of this, but it's something that we're going to put off for the FSAR.

So it's -- that's part of it, too, making -- again, making sure that they had a comprehensive understanding. And that's guided by NUREG-1537. And the reviewers looked at -- did they talk about this? Did they talk about this? Did they talk about this? And then that would generate questions to make sure there was a --

(Simultaneous speaking.)

MEMBER POWERS: No, I'm just trying to understand how you decide between them. And I can understand that first between resolve it now, resolve it later where it goes in as a commitment. The selection between those two I'm a little hazy on right now.

MR. LYNCH: Sure, and I think some of that -- and issues that need to be resolved prior to the completion of construction we'll go into more detail in a couple slides, but those are those issues that we've created conditions for. And a lot of that has to do with criticality controls. And that's where we fall on a lot of those items that need to be resolved before the completion of construction.

For example, with the CAAS, making sure that -- while they -- it may be conservatively designed such that workers are protected from radiation exposure, but if they go overboard, maybe the alarm system doesn't work as it's intended to because it's also shielded from the radiation.

So those are the kind of items that we want to highlight during our Construction Inspection Program for those items that we maybe don't need to see until the operating license application. That may be specifics with their -- any digital systems they might use. That isn't going to necessarily impact the pouring the concrete.

MR. BALAZIK: So I just want to go over the Appendix A that's in the SER and just highlight the different areas.

Appendix A.1 is the proposed licensing conditions, and we'll talk about some of these in a minute.

A.2 was the regulatory commitments identified in response to RAIs. So if we asked an RAI and Northwest said that we can supply that information with the operating license, we captured that in Appendix Alpha.2.

Alpha.3 identifies the regulatory commitments that were fulfilled by Northwest, in saying that their response to the RAI was complete and it was accepted by the NRC.

Alpha.4 were commitments that we identified during the ACRS Subcommittees. And we'll look at a table real quick that has a couple of those items and we'll touch on a couple of them.

And Alpha.5 is just the ongoing research and development.

So let's talk about the proposed licensing conditions. These first two are on criticality. The first one is on the upper subcritical limit. As a result of requests for additional information, Northwest revised their upper subcritical limit, however, that new limit has not been incorporated into all their design calculations. It will take a little bit -- awhile to do that. So we came up with -- this licensing condition was proposed to ensure that Northwest incorporates that revised upper subcritical limit in their design. And this has the potential of impacting construction.

For example, for a certain tank or certain spacing to get to that new upper subcritical limit the dimensions could change. Right now it's not, no, but it could actually impact that. So this first licensing condition addresses that item.

The second one, as Steve mentioned earlier, was on the CAAS. If you pour a certain amount of concrete, the CAAS might not be able to detect a criticality. So we wanted to address this one that they will provide a technical basis for the design of the CAAS and notify the NRC prior to completion of construction.

MR. LYNCH: And with each of these conditions while we are asking that the applicant provide us periodic updates on the status of their design as they resolve these items, the staff will not be performing technical reviews based on the information provided with these conditions. They will be ministerial in nature. And what we will use them for is input into our Construction Inspection Program. It will help us provide information to our inspectors to help them prioritize those most safety-significant items when they are on the site and conducting inspections.

MEMBER KIRCHNER: This sounds -- on the

surface it looks okay. The problem that I see is that you have six-month intervals and they're on a rather ambitious construction schedule. I'm just looking at start of site prep construction, second quarter of '18, end of construction, second quarter of '19. So basically they're planning on a year to build the facility. So how does this work in practice?

MR. BALAZIK: Well, one thing that -- to --

MEMBER KIRCHNER; And again --

MR. BALAZIK: -- for a licensing condition you have to have --

MEMBER KIRCHNER: And one other comment I --

MR. BALAZIK: Yes.

MEMBER KIRCHNER: -- should make first. Following the applicant's design philosophy of first going with passive measures, passive measures means space basically and piping dimensions. And that sooner or later impacts concrete and so on if you don't have enough space.

So I'm just -- although this makes sense, in practice it looks like they're on a pretty fast track schedule.

MR. BALAZIK: Yes, sir.

MEMBER KIRCHNER: Can you take information from them, review it quick enough to actually have an impact before you get an unwanted result that may cause back -- I don't want to use that word -- change in the design or the construction?

MR. LYNCH: Sure. So in addition to responses to these conditions the staff will have other opportunities to look at these -- the design as it evolves. We have an expectation that the applicant will maintain a -- some sort of either physical library or digital library documenting their design control and design changes as they go through construction so that when inspectors arrive on the facility, they have more than just the preliminary safety analysis report to go by. They need to have what does the current design at the facility look like?

So all of these design changes should be documented, whether it's been submitted to the NRC within the six-month interval. That should be available on site so that inspectors can look at that. And it's expected that they will be keeping this documentation up to date on site even if they haven't submitted it to the NRC. Part of the selection of the six-month interval is to try to allow the applicant to focus on their design changes instead of being burdened with administrative preparation of documents. So while they may not submit every six months, the expectation is that this information is continuously updated and available on site for inspectors to look at in the preparation of their inspections.

MEMBER KIRCHNER: This implies then you have dedicated staff to this while they're doing the construction --

MR. LYNCH: We do have --

MEMBER KIRCHNER: -- not just the inspectors, but criticality experts, etcetera?

MR. LYNCH: Yes, we do have staff both in NMSS for -- that are criticality experts that are supporting us and providing ongoing support. We also have staff out of Region II, inspectors that are helping us develop inspection plans. And we meet monthly to discuss the updates of what we've been looking at in preparation for construction --

(Simultaneous speaking.)

MEMBER KIRCHNER: What I'm just probing is this requires a commitment from you. You asked for this information on this interval. They're on a rather fast track schedule. It's going to require a responsiveness by the regulatory group.

MR. BALAZIK: Yes, sir. And one thing I'd like to add to Steve's point is there's also a termination for both of these licensing conditions. Basically when Northwest submits the final design, these can go away because we have all the information. We have their final design and we can start reviewing it. So both of these licensing conditions, I use the word "terminate" once they submit their FSAR or operating license also.

All right. So we talked about technical license conditions. The third one is more administrative. Now Northwest is required to have a Quality Assurance Program in accordance with 50.34, however, Appendix B of Part 50 does not apply to them. So this licensing condition kind of holds Northwest to their Quality Assurance Program. And if they make changes to that Quality Assurance Program, they need to notify the NRC. And this licensing condition is similar to the requirements in 50.55(f) for implementing approved change to a Quality Assurance Program, which is applicable to power reactors and fuel processing permit holders.

And I'll say that during our discussions in construction inspection in lessons learned we kind of came up with this licensing condition to hold them to their quality assurance, because it's the basis for construction and if they're changing it, we want to know.

MR. ADAMS: And this is one of the first areas where the inspectors will focus to verify that this Quality Assurance Plan is up and running and being effective.

MEMBER KIRCHNER: So much is made of the fact that this is not -- Appendix B is not applicable, but I scratch my head in a sense because I can't imagine a Quality Assurance Program that you would accept that wouldn't essentially be the ANSI/ASME standard, and hence the 18 parts to the program, etcetera.

MR. LYNCH: If you look at our --

MEMBER KIRCHNER: So I assume you're --

MR. LYNCH: The ANSI standard, yes.

MEMBER KIRCHNER: You're going to the ANSI standard, right?

MR. LYNCH: Correct, ANSI Standard 15.8 if you compare it to Appendix B, there's been a lot of -- it's maybe 90 percent the exact same language, same criteria.

MEMBER KIRCHNER: It's derivative of the --

MR. LYNCH: But what the differences are it acknowledges that staffing at these facilities may be different than at a large company and that the technology may be different as well.

MR. BALAZIK: It talks about experiments also --

(Simultaneous speaking.)

MEMBER KIRCHNER: We hear this also from new reactors, and I just again scratch my head and say but what's really different other than --

MR. ADAMS: Well, this -- so I'm on the ANS Standards Committee and this standard was written because Appendix B didn't apply. So there was a vacuum that needed to be filled in and it was filled in by the standard. And as Steve and Mike said, if you read the standard, you're going to see a lot of parallels to Appendix B.

MR. BALAZIK: All right. Real quick I just want to go through Appendix A.4, which is the regulatory commitments identified through ACRS Subcommittee meetings. I'll just touch on the first item; Northwest mentioned this earlier, is the seismic, about the high-frequency impact to the site.

And on the next one I just want to touch upon the third one which will reexamine the accuracy of its estimates for aircraft takeoff and landings at the Columbia Regional Airport. That's another item. And I want to talk about that real quick.

So during the Subcommittee meetings there were several errors that were identified in the Northwest aircraft impact analysis, so the staff performed a confirmatory analysis. And see the table below with Northwest compared to the NRC staff, that the total impact frequency calculated by the NRC staff is on the same order of magnitude calculated by Northwest and that the staff concludes that Northwest should evaluate the impact of a general aviation crash.

And the reviewer for this identified a lot of errors: inconsistent flight operations; and these were brought up during the Subcommittee meeting, incorrect crash rates for specific aircraft, inconsistent non-airport crash frequencies. And then there was just errors between tables. In other words, the information was developed and the incorrect information was put in another table. But we came relatively close to what Northwest had on their total aircraft impact frequency.

So captures in A.4 that Northwest will examine and ensure. I kind of already mentioned this.

And Northwest commits to resolve all the discrepancies in the data during the final design and be operating license application. And the staff will further review that the aircraft impact analysis and the FSAR to ensure that these deficiencies are corrected.

MEMBER STETKAR: Mike, this morning you highlighted the aircraft crash, but we had quite a bit of discussion certainly about the aircraft crash, but we also had discussions about the analysis of pipeline accidents where the staff has not identified a pipeline that's in fact closest to the facility. We also had discussions about highway accidents and the methodology and values that were used to quantify the frequency of those highway accidents.

It's my understanding that Northwest is going to re-perform all of those analyses, not just the aircraft crash. You highlighted the aircraft crash this morning as something that's continuing, but that all of those kind of -- I'll throw them in the ballpark of manmade external hazards, if you will -- will be revisited for the operating license, at least the three that I mentioned: the pipeline, the highway transportation and the aircraft.

And the reason that I focused on these is that this is an area where there is guidance and there are -- I hate to use the word "criteria." There are values that are applied where if during the construction permit application process and review the applicant can justify, for example, that based on their analyses the frequency of an aircraft impact is less than 10 to the minus 7 per year, that will not be revisited. I mean, that's something that the staff does not reopen during the operating license process because it's a conclusion that's made.

And that's one of the reasons why I think that we focus during the Subcommittee meetings on those issues, because quite frankly it's not fair to them to come back and say, oh, wait a minute, what's -- let's redo an analysis that the staff has already accepted that meets some sort of criteria, a site-related analysis. So that was one of the reasons that we paid particular attention, the errors and omissions notwithstanding.

MR. ADAMS: And again, taking -- approaching the operating license from a clean look at things, we will take another look at the site criteria.

MR. BALAZIK: Just real quick I want to mention the status of the Northwest review. As of October of this year Northwest has adequately responded to all requests for additional information. also PSAR Rev. 3 is in ADAMS. It was put in ADAMS on September 14th, 2017, and there's the ADAMS accession number for that.

The final Environmental Impact Statement was published in May of 2017 in NUREG-2209. And the Safety Evaluation Report is in concurrence and the staff is set for issuance of that in November 2017. As of right now the mandatory hearing for the construction permit is scheduled for January 23rd of next year.

I just kind of want to go through these relatively quick because I know we're running behind, but just talk about a couple of the findings.

MEMBER POWERS: We're in fine shape.

MR. BALAZIK: We're okay? Okay. All right.

MEMBER POWERS: Yes, take your time.

MR. ADAMS: Thank you.

MEMBER POWERS: I know you want to get out of here.

(Laughter.)

MEMBER POWERS: But Al tells us that he is so happy to be here that I don't want to deprive him of a single minute of the pleasure that he's providing to --

MR. ADAMS: Full happiness.

MEMBER POWERS: Yes.

MR. BALAZIK: All right. So for the regulatory basis for the construction permit the following findings need to be made based on 50.35, that the facility design has been described including the principal design and engineering criteria for the design. The technical and design information that may be required to complete the safety analysis can be reasonable left for later. And that safety features or components requiring research and development have been identified and they will be conducted in a Research and Development Program designed to answer these questions. And that all safety questions will be resolved prior to completion of construction of the proposed facility. Also there's some conclusions that we need to make in 50.40 and 50.50, and we'll talk about those in a second.

So for 50.35(a)(1) the facility design has been described. The staff evaluated the preliminary design to ensure sufficiency of the principal design criteria, design bases, materials of construction, general arrangement, and approximate dimensions. Also, when necessary if the staff needed more information, it was requested. And the staff finds that there is reasonable assurance that the final design will conform to the design basis, provide an adequate margin for safety, provide for the prevention and mitigation of accidents, and meets applicable regulatory requirements and acceptance criteria.

35(a)(2) findings, that such technical or design information may be required to complete the safety analysis can be left for later consideration. Staff evaluated the sufficiency of the preliminary design of the production facility based on Northwest's design methodology and ability to provide reasonable assurance that the final design will conform to the design basis with adequate margin of safety.

Throughout the PSAR and in response to the RAIs Northwest has indicated that there are areas that require further technical design information. And the staff is tracking all these items as I mentioned earlier in Appendix Alpha. So staff finds that Northwest has provided reasonable assurance that further technical or design information can reasonably be left for the submittal of the FSAR.

The 50.35(a)(3) finding, which is safety features or components requiring research and development. Northwest has identified four research and development activities, and they're documented in the appendix. Irradiation and corrosion testing. There was some resin testing, ion column pressure relief testing, and the evaluation release of -- I'm just going to call it DAP from the ion exchange column during operation.

Staff finds that Northwest has adequately described Research and Development Program and that additional information needed on certain matters related to nuclear criticality safety, and these were included in the licensing conditions.

For the (a)(4) finding that there's reasonable assurance that safety questions will be satisfactorily resolved at or before the latest date specified in the application for completion of construction. Right now the date, the latest date for construction is December 31st, 2022. So based on research and development schedules Northwest expects to resolve these safety questions prior to completion of construction. And also that the permit conditions must be satisfied prior to completion of construction. And that's more for the two criticality licensing conditions.

Staff finds there's reasonable assurance that Northwest's research and development activities will be satisfactorily completed at or before the latest date of completion of construction of the production facility.

Another one of the findings is that there is reasonable assurance that taking into consideration site criteria contained in 100 that the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public. So while -- we kind of mentioned this earlier about the Part 100 site criteria not applying to this facility, but we considered similar site-specific conditions in SER chapter 2, and also in SER chapter 3.

Staff confirmed that chapters 11 and 13 of radiological releases during normal and accident scenarios would be within the Part 20 limits based on the reviews of applicant's use of 10 CFR Part 70 integrated safety analysis methodologies.

MEMBER KIRCHNER: May I ask my question from earlier again? When staff confirmed, you confirmed methodologies or you independently did a calculation of the bounding source terms that then are used to demonstrate that you're within the 10 CFR Part 20 limits? And which could did you use, if you did it?

MR. LYNCH: So at this time we did focus on confirming methodologies.

MEMBER KIRCHNER: In other words, what code they're going to use to calculate the source term? They actually did estimates of the -- of a bounding source term.

MR. BALAZIK: Well, I know that the code was looked at. I know that we looked at inputs, but right now we just looked more of the methodology that they used and did not do an independent confirmatory calculation.

MEMBER KIRCHNER: I guess I'm surprised because chapter 13 hangs on coming in within this bounding estimate that they provided you. Otherwise, you're just checking process. I know they have a nice thorough listing of all accident categories and such, but that's more a process than actually confirming.

MR. ADAMS: I think there were some calculations done. I'd have to go and take a look at the SER. Unfortunately that technical reviewer couldn't be with us today. I'll try to take a look and see.

MEMBER KIRCHNER: And, Al, when you look at that, could you also inquire which code you used? That's a leading question for --

MR. ADAMS: Yes.

MEMBER KIRCHNER: -- our research review. Thank you.

MR. NAQUIN: I'm Ty Naquin. I did the RP review for chapter 11. I can't speak for chapter 13, but for the normal operating conditions I used the RASCAL code for assessing what they've done and found that they were consistent.

MEMBER KIRCHNER: Thank you.

MR. BALAZIK: So this is our last slide. As I mentioned earlier, there were some other regulations: 50.40, 50.50 considerations, and these are that the construction of the facility will not endanger the health and safety in the public and that construction activities can be conducted in compliance with the Commission's regulations, that Northwest is technically and financially qualified to engage in construction and the issuance of the construction permit will not be inimical to the common defense and security of the health and safety of the public, and that the application meets the standards and requirements of the Atomic Energy Act and the Commission's regulations.

And with that, that ends the staff's presentations, and I guess we'll open it up for more questions.

MEMBER POWERS: Do any of the members have any additional questions?

(No audible response.)

MEMBER POWERS: I don't see anybody with additional questions. We have now a protocol for calling out comments from the audience. Are there anybody in -- is there anybody in the audience that would care to make a comment?

(No audible response.)

MEMBER POWERS: I don't see a massive rush to the phone.

We now have a protocol for people making a comment on the line, and I don't remember what that is, so I will defer to Mr. Bley to go through that litany.

CHAIRMAN BLEY: The protocol is simply to ask if someone on the line would like to make a comment. identify yourself and make your comment, please.

MS. THOMAS: Does that include members of the public?

CHAIRMAN BLEY: Absolutely. Please go ahead.

MS. THOMAS: This is Ruth Thomas and I was

-- had some questions about what this is based on, like what the pilot is or the model. Is this based on other facilities that have done recovery of molybdenum like there was in Canada?

CHAIRMAN BLEY: Ruth, this is a time just for public comments, so we -- it's for our gathering information, not a time for the public to ask questions. I'm sorry. If you have any comment though, we'd be glad to consider it.

MS. THOMAS: I thought you were asking for anybody's questions.

CHAIRMAN BLEY: Not questions. Just comments. But if there are things you'd like us to consider, please tell us and we will consider them in our deliberations.

MS. THOMAS: Oh, you mean it should be in the form of a comment --

CHAIRMAN BLEY: That's right.

MS. THOMAS: -- instead of a question?

CHAIRMAN BLEY: That's correct.

MS. THOMAS: Well, the comment that I have is it's not clear what the basis for all this is. Is this completely new -- let's see, how can I form that as a statement? That this is not -- this is new technology.

CHAIRMAN BLEY: All right. Thank you. We will consider that. Anything else? Or there anyone else on the line who would like to make a comment?

(No audible response.)

CHAIRMAN BLEY: Dr. Powers, are you complete?

MEMBER POWERS: Thank you, Mr. Bley, You admirably carried out our protocol.

CHAIRMAN BLEY: Thank you, Dr. Powers.

MEMBER POWERS: I thank the staff. It was a very useful presentation. I thank the applicant. An equally useful presentation.

Mr. Bley, I turn the meeting over to you.

CHAIRMAN BLEY: Thank you very much.

At this time we will take a break for 15 minutes. You're ready to go through the letter, sir?

MEMBER POWERS: We want to make some adjustments to the letter, so we may not be instantly ready, but shortly.

CHAIRMAN BLEY: Fifteen-twenty minutes enough?

MEMBER POWERS: I think so.

CHAIRMAN BLEY: We will come back at 10:30 to reconvene, but we are off the record until 1:00.

(Whereupon, the above-entitled matter went off the record at 10:07 a.m. and resumed at 12:59 p.m.)

CHAIRMAN BLEY: We are back in session for the afternoon. Just a reminder to everybody, since we didn't go into closed session, the webcast continues this afternoon.

I'm going to turn the meeting over to Mr. Stetkar at this time for the SOARCA discussion.

MEMBER STETKAR: Thank you, Mr. Chairman. I'll keep this brief. For those of you who have not been around for the last decade, this is the third installment of the SOARCA series, the Sequoyah plant. We've been reviewing this material at the subcommittee level for almost a year and a half. We had meetings back in May of last year, June of this year, and latest one of October of this year. And we'll let the staff explain the current status of the project, and I'll turn it over to Pat Santiago from Research. Pat.

MS. SANTIAGO: Thank you. Good afternoon. I'm Pat Santiago. I'm Chief of the Accident Analysis Branch in the Office of Nuclear Regulatory Research, and today I have with me Dr. Hossein Esmaili from the Fuel and Source Term Code Development Branch and Dr. Tina Ghosh also with the Accident Analysis Branch who will be presenting.

We appreciate all the feedback, as Dr. Stetkar indicated, over the last year and a half and, in particular, from the October 18th, 2017 subcommittee review meeting. The SOARCA team has been working diligently over the last number of months to respond and address many of the comments that were provided to us, and we continue to work on them.

I want to acknowledge once again the numerous team members that have supported and contributed to this Sequoyah SOARCA project. We have a slide toward the end of the briefing that lists these team members, and we have a handful of them in the audience here from NRC, as well as Sandia, and we have several on the bridgeline.

As a short outline for today's presentation, I'm going to do an overview and I'll discuss the uses of the SOARCA modeling, and Hossein will discuss the Sequoyah short-term station blackout analysis, and Tina will discuss lessons learned, and then we'll conclude.

This slide provides a quick overview. We had several goals and objectives for the SOARCA project when we initiated it. John says ten years ago. I wasn't here ten years ago, but we'll give you that. I'm sure it has --

MEMBER STETKAR: I was surprised. I was looking it up, and I didn't go way back, but I know the last letter that the ACRS wrote on it was 2012, which is five years ago, and it was --

MS. SANTIAGO: And I joined the team in late 2010, I think. But it's been a heroic effort, I have to say. So I've listed two key goals and objectives we had for the SOARCA project. And for the Sequoyah analysis, we had two additional objectives. One was to also develop knowledge on how the ice condenser containment design responds in severe accidents, as well as develop technical insights to support the Agency's Near-Term Task Force (NTTF) recommendations, specifically 5.2 which was related to reliable venting for other than Mark I and II containments and 6 related to hydrogen control and mitigation.

After the completion of the Peach Bottom and Surry pilot plant analyses in 2012, staff had recommended a limited analysis for this third plant with an ice condenser containment, as well as a scenario for Surry uncertainty analysis in order to extend the BWR uncertainty analysis insights to a PWR with a large dry containment.

And the Commission approved the staff

recommendations in SRM-SECY-2012-0092, noting that these additional limited analyses should complement and support the Level 3 probabilistic risk assessment project and certain NTTF activities. The Surry UA is helping the Level 3 PRA project by identifying key sources of uncertainty, and the Sequoyah analysis has helped generate the technical basis for staff's closure of the NTTF recommendations 5.2 and 6.

Our Sequoyah analysis is going to be published as NUREG CR and is due to the Commission on November 30th. We also will be sending that report to publications at the same time.

It's essential, I think, to identify the importance of the SOARCA methodologies and analyses that we've been conducting over the last number of years. These analyses and approved models have supported numerous Agency activities, and we appreciate the ACRS's recommendations over the years and the review of this project, as well as the research program. And you've encouraged the NRC to focus on modernizing the severe accident analysis codes and accelerate efforts to implement improved models, which we are doing.

The list on this slide and the next is not comprehensive, but I've tried to categorize the work and how essential it is to support the Agency's safety and security mission. Some general categories include technical bases, licensing reviews, informing severe accident guidelines, and insight for emergent issues as was done during the Fukushima event.

Most recently, the newer MELCOR MACCS models were used for the containment protection and release reduction analysis, which I think you also were briefed on about a year ago. And MACCS is currently being used to support the economic cost benefit analyses performed for regulatory analysis and updates to that guidance. We use these models to understand what's occurring so we can answer the questions to the best of our current knowledge and capability, and there's still more work to be done. As you know, we'll be seeing you in another two weeks on the Level 3 PRA.

In future analyses that we looking to consider, we're considering the new small modular reactor designs due to the single and multiple module issues that affect accident progression, mitigation, emergency planning, and off-site consequences. And we've had several questions that have come out of the topical report reviews we've done.

This slide talks again about the work

we've used the MELCOR MACCS models for in support of the response to the Fukushima events. The SOARCA analyses are used in our training classes provided at the NRC. We understand industry also offers training, and they use these different analyses.

We have international groups also pursuing SOARCA-like studies. Korea Hydro and Nuclear Power Company is completing a SOARCA-like effort on the APR1400 design at the Shin Kori site, and we're following that, as well.

So to better understand these new designs, our staff benefit by these analyses for knowledge, development, and to maintain core competencies in severe accident capabilities. In the mid-2000s, our capability was limited, and after 2010 it has improved. And, yet, as you realize, it's not a technical expertise that you can really develop easily. We really need to maintain this capability since you can't develop it in the middle of an emergency.

In light of this, we continue to support a lot of accident knowledge management initiatives, and we are continuing to engage in domestic and international activities.

At this time, I'd like to turn it over to

Hossein to talk about the short-term station blackout.

MR. ESMAILI: Okay. So this is just, as a reminder, an overview of the high-level observation we made back in, I guess June it was and also last month. I wanted to give you what are the things that stand out and, you know, how these things are controlling what we are seeing in terms of overall conclusions.

The first one is intuitive. The consequences are strongly dependent on early versus late containment failure, so later failures are less consequential. But the next three bullets in terms of hydrogen combustion and the behavior of the safety valves are more interesting, and this is the one that we are going to focus on.

So the second bullet is saying early containment failure occurs only under forced hydrogen burn. So we have to remember this, as I go through the slides, is that the subsequent hydrogen burns do not have enough hydrogen or energy to fail the containment. So you either get it at the first burn or you're going to have later burns that are not sufficient to cause the containment to fail. So this is important.

So bullet number three is kind of related to this. When you have protracted safety valve cycling, that means that the safety valve is cycling up to the time of hot leg failure, etcetera. In general, you are producing lower in-vessel hydrogen by the time of the first phase, so this is tied to how much hydrogen we produce by the time we burn it.

There are a number of reasons for it. You know, we can go through some of the calculations. The core heat-up is actually slower. There is more efficient heat transfer from the core to the boundaries to the hot leg in particular, and there is less temperature difference between the core and hot leg, and this is the same as a high pressure. So the creep rupture occurs relatively soon, and the hydrogen is less. So at that time, you know, you have accumulator injection that kind of arrests, you know, whatever oxidation that you're going to get after that.

On the other side, if the pressurizer fails to close, you have, you know, depressurization of the primary system, what happens is that you have longer time, you produce more hydrogen, there is more steam available to produce hydrogen, and there's access to the steam. And as the system is depressurizing, accumulators can intermittently inject so there is fresh water for oxidation. So in these cases, when we have pressurization of the primary system, we produce more hydrogen. At the same time, because now the system is at lower pressure, we have to get these things hotter for any failure of the pressure boundary.

VICE CHAIRMAN CORRADINI: So can I just say it back to you on two, three, and four? Because I'm trying to key on a couple of key events. But the key event is the accumulator discharges. My impression of three and four is that, if I have held it at a high enough pressure, I don't get essentially a fresh supply of water, or is it more than that?

MR. ESMAILI: No, if you have -- so the third bullet is that you are cycling at system pressure, 16 megapascal, until your hot leg fails. So you don't have any accumulator injection in these cases. At that point, you have a sudden injection of the accumulator.

By that time, by that time, when this happens, and I think this one was what Casey showed you last time, is that you have lower in-vessel hydrogen generation and, at the same time, the core is relatively intact. So you are heating up the --

MEMBER STETKAR: Well, but, also, Hossein, the hydrogen that was generated, by definition, burns when the hot leg fails, so you get no further accumulation anywhere.

MR. ESMAILI: Right, yes. So the hydrogen that is -- it can go out, but most of the hydrogen is actually bottled up inside the RPV. And then when the hot leg fails, it just rushes up. But by that time, you already have an ignition source, which is the hot leg --

MEMBER STETKAR: Yes, and it burns.

MR. ESMAILI: Yes, and it burns. I don't know whether that answered your --

VICE CHAIRMAN CORRADINI: Well, my way of thinking about things are physical events that lead me up a certain branch point. And so the branch point for four is that -- I'm sorry -- for three, excuse me, is that I don't get a depressurization early due to safety valve. They keep on cycling --

MR. ESMAILI: Just keep on cycling.

VICE CHAIRMAN CORRADINI: -- so that I, when I do get it, I get an ignition source just where I'm essentially releasing.

MR. ESMAILI: Right.

VICE CHAIRMAN CORRADINI: So it's a combination of no extra water early and an ignition source when I do get the hydrogen out into containment.

MR. ESMAILI: Right.

VICE CHAIRMAN CORRADINI: Okay.

MR. ESMAILI: And during this process --

VICE CHAIRMAN CORRADINI: Adversely, in four, I get it open early, I get more water, and look out.

MR. ESMAILI: Right. It's a little bit more into it because when you have lower in-vessel hydrogen, when it's cycling, you're actually transferring more heat more efficiently to the hot leg. So heat is just inside the vessel, and then you have less time from the time that hydrogen generation occurs until you have the hot leg failure and the hydrogen burn. So we have to keep these three in mind that these are the big items that actually we were focusing on.

VICE CHAIRMAN CORRADINI: And so now can I take bullets three and four and connect them to two, given that we --

MR. ESMAILI: Yes, yes.

VICE CHAIRMAN CORRADINI: -- think we --

MR. ESMAILI: That's the --

VICE CHAIRMAN CORRADINI: -- three and

four. When I have an early cycling failure, that then drives it --

MR. ESMAILI: Right.

VICE CHAIRMAN CORRADINI: Okay.

MR. ESMAILI: So, actually, I'm going to go to slide number -- so the last one is tied to the first two, you know, the leg containment failure are less consequential and you have more time for fission products to settle.

So next slide, please. Okay. So this one I have already shown you. This is trying to capture what I said in that, what I said before about bullets two, three, and four, that when you are depressurizing you are producing more hydrogen. You have more time. You have more time to vent this hydrogen into the containment. So by the time you have a failure or you have an ignition source that becomes available, then you have enough hydrogen to fail the containment.

On the left-hand side, you know, less than about 300, those are the high-pressure cases. The system is cycling that high pressure. So everything to the left of the figure, you know, everything to the left of the figure are high-pressure cases, everything to the right of the figure are low-pressure cases.

And what we found out in the new

uncertainty analysis is that we have less points because of this behavior of the safety valves. And I have to say this because we discussed extensively last time, and Tina was on the hot seat. So we have limited data. This does not allow high confidence in terms of the distribution for safety failure. So you can see in the draft UA we had 62 percent of the cases leading to failure to close. In the new one, we only have 4 percent.

But what it does show us is that if we know how these safety valves behave, I know where I'm going to be in --

MEMBER STETKAR: Hossein, I'll try to be good. To me, the evolution of this information, going from the bar on the left to the bar on the right, shows the importance of doing a realistic integrated engineering uncertainty analysis because the only difference in these results is driven by the uncertainties. It's not driven by the valve failure rate. The valve failure rate, the fundamental valve failure rate has remained essentially the same. It's the change in the uncertainty and the uncertainty in the size of the open area, given the fact that it does fail to re-close. And that's, I think, one of the messages from this study that's really important, that the uncertainty analysis is integral to the results. It's not something that's an afterthought that you say, well, I do the analysis with something that I'll call a number -- I won't give it a characterization -- and then, as an afterthought, do the uncertainty analysis and say, okay, I did an uncertainty analysis. It honestly has had a measurable, a measurable effect on the results of the study and the conclusions that you've drawn from the study.

MR. ESMAILI: Absolutely. I 100-percent agree.

MEMBER STETKAR: So regardless of, you know, what the level of uncertainty is and what the actual failure rate might be, I think it's something that we've collectively learned over the last couple of years that we've been looking at this, this particular study.

MR. ESMAILI: And this is very helpful for us as we try to understand these accidents. Now, remember during the Fukushima that people were having, you know, opening up the SOARCA, you know, for Peach Bottom and trying to see where we are. So this type of analysis, this is a very simple map that tells you if I'm in this space, you know, maybe I am producing less hydrogen. So I can go ahead and check against other measurements, etcetera. So it's useful in a number of ways.

And the reason we did this, actually, is that we were struggling to describe what happens because we had less failures this time compared to the last time. But everything falls into place.

So on the next figure, so this one we didn't show last time, but I added the beginning of the cycle and then I superimposed the long-term station blackout. And here I just wanted to make a point that, so this is all the current UA. And in the insert, you see the K curve. So you see the clustering of the yellow and the pink on the left-hand side of the figure. This is where the decay heat are more similar, and it takes -- so, basically, when you have the decay heat lower, you know, it takes a lot longer time for it to boil off and heat transfer, etcetera. And then when you see the middle of cycle and the end of the cycle, you know, those behave, more or less, the same. So the green and the blue behave similarly in this figure because you have the same decay curve, and the yellow, which is the beginning of the cycle, and the pink behave more similarly.

The other thing I wanted to show you is that this came up a few times last time, but you see there are some beginning of the cycle, there's some guys sitting over there in the 400 region. And we did not get any early containment failure from the beginning of cycle cases, but this one clearly shows that it is quite possible. There are cases that could lead us to vessel depressurization and put us in the region that we can -- it's just that we didn't have enough samples.

MEMBER STETKAR: You're not going to talk about the focus study. You picked up a few beginning of the cycle --

MR. ESMAILI: Right.

MEMBER STETKAR: -- cases when you looked in that regime.

MR. ESMAILI: Yes, yes. So I'm going to get into that later. But this is, what it shows that -- and, actually, the shape of the curve is also important. As you can see, you go to the left, it's trying to go towards infinity, you know, because you're producing less hydrogen, so, obviously, you don't have time. Deflagration is going to go up.

Next slide, please. All right. So here is the -- so we got questioned last time because of these code failures. So I want to say a few words about these code failures and try to convince you that this is not going to change our overall conclusions, and I think my last takeaway from the last meeting was that use engineering judgment in trying to explain. And this is what we have been trying to do because of the, you know, the time limitation.

So just to give you a little bit of background, for each uncertainty analysis that we do, what the code development team does is it looks at the input deck and looks at the code and tries to shake down the input model, the code, etcetera, and the aim is actually to reduce errors to lead to code failure because, once you submit 600 cases, then it's out of your hands. We don't want to go back and try to baby each one of these realizations.

So during this process, our focus is on the common-cause failures. And I think you pointed out that, whether it's in this region or whether in the focus study, when we are in this high hydrogen cases, you know, to the right of the figure, we have more failures, as opposed to when we are to the left of the figure because in this one we are producing more hydrogen, the core is more damaged, your accumulators are injecting, etcetera. So it's more challenging to do the calculations, so we expect more errors.

MEMBER STETKAR: Hossein, just before we get too much into the details here, not all of our members attended all of the subcommittee meetings. So what Hossein is trying to address here is there was an observation that, round numbers, about 40 percent of the MELCOR attempted realizations in the area that he's going to focus on, in other words if I can call it a regime of the accident progression, about 40 percent of the runs failed to complete. And that's kind of troubling because you don't necessarily know what might happen if those runs did go to completion. For the runs that did complete, a certain fraction of those runs went to early containment failure and another fraction didn't go to early containment failure.

So the question is, well, number one, why didn't the runs complete? And number two, is there anything that can be done to infer what fraction of those runs that didn't complete would go to early containment failure? Is it the same fraction, or is it wildly different? That's just background for the folks who weren't here.

MR. ESMAILI: Absolutely. But I just want to emphasize the point that I get a little bit defensive, I guess, when this 60-percent success rate.

The overall success rate of these calculations that we did was 95 percent. So when we submitted 600 runs, we got 567 of them going to completion over three days. It was just in that particular region that the code had issues.

MEMBER STETKAR: If I tried to drive to the grocery store five times a day every day, and most of the time it's sunny and dry, I succeed most of the time. If it's really bad, then I might have a much higher failure rate. So counting up successes in the areas of the transient that are not necessarily challenging the code doesn't really --

MEMBER KIRCHNER: What was the source of failed to complete? I'm waiting to hear the answer why it didn't complete.

MR. ESMAILI: So as I said, as I said, these cases are challenging because the core is severely damaged. And so what you have is that you have, you have relocation of the core. At the same time, you have accumulator injection, etcetera. Sometimes, we have convergence problems because, you know, part of the core cell is occupied by a lot of molten material and particulate debris. And so you have to, this is nothing --

MEMBER KIRCHNER: What is it in the

physical modeling that prevents it from completing the run?

MR. ESMAILI: As I said, so --

MEMBER KIRCHNER: It's not the physics of what's happening. It's something in the calculational methodology.

MR. ESMAILI: Right. And then there could be some errors also. Remember, when we did the draft UA, we were able to go ahead and fix those errors, so we got a better success rate. Here, we did not think it was -- first of all, we didn't have time and resources to go back and do it, go back to Larry at Sandia and fix all of those cases that led to failure. The one that --

MEMBER KIRCHNER: When you first said failure to complete, I was thinking that the code was just grinding along and wasn't getting to an answer, and so you just truncated it after running so many CPU hours.

MR. ESMAILI: Yes, sometimes it tries to, it asks for lower and lower time steps because it cannot converge in one particular cell because there's not that much hydrodynamic volume. What we really do is that, if we are not doing uncertainty analysis, sometimes you are able to go back, change the parameters, iteration parameters, etcetera, change the time step and let the code move forward.

Sometimes, since this is systematic, since what we saw here is systematic that we saw also in the focused SV, that means that there must be some errors in how the relocation is occurring. So but --

MEMBER KIRCHNER: Errors in the code?

MR. ESMAILI: Errors in the card potentially.

MEMBER KIRCHNER: I think what you need to be careful about is separating out what's a numerical difficulty from the physical result, and I'm not getting quite the distinction.

MR. ESMAILI: And, again, as I said, we did not go back and look at every single one of these cases. Part of the reason was that now, when we did this calculation, we did these calculations with a certain version of the code. Now we are past that version. We have done multiple corrections to the code. So we were just making an engineering, you know, judgment. Do we want to go back and try to resolve all these cases. When I talked to Larry, Larry said, yes, we could, we could go back and those ten cases that you see here with the red, we could go back and look at all those individual cases and see what happened and make them go to completion. Sometimes, it would be take, it would be a matter of maybe a few hours. Sometimes, it would take weeks to uncover what led to that failure. So we did not have the time and we did not think this would affect our overall conclusions, in terms of having, you know, what is the potential for early containment failure.

So what I'm showing you is that those red dots that I'm showing you right now, these are the phases that failed, that failed to run to completion because of the convergence problems, but they produced this much hydrogen by the time that the first deflagration occurred. So this is what engineering judgment comes in and see, you know, do we want to back to the earlier version of the code and debug it, or do we want to move forward and do this?

CHAIRMAN BLEY: Hossein, you seem reluctant to say we don't know.

MR. ESMAILI: Yes, we don't know. Yes, yes, we don't know because we didn't go back and --

CHAIRMAN BLEY: That's the first thing. The second thing is, and it's related to what Walt just asked, were these cases where it keeps trying to run, or did it actually stop running? Did it blow up on something --

MR. ESMAILI: That actually makes a very -- the code, most of the time, it has a number of iterations. For example, it says, you know, I have hit my number of -- I cannot move forward, I need lower time steps. Sometimes, if I'm not doing UA, sometimes, if I'm doing these things, I go back before it fails, I change the time step, and it changes the core relocation and I can go past it. This is what usually users do. They shake down the model. For the UA, we could do not do that, so we decided to look at, you know, start running it and see whether it makes any difference in our overall conclusions.

You are right, we don't know. We can go back and look at these things. We did not think that it was important because, by the time -- so the thing is if I wanted to answer how many early containment failures I have, I already know I have very, very few early containment failure cases because it's tied to how my safety valves behave. I'm already, in this case, I already have few cases. I have 23 of these cases that actually led, that went to completion, you know, in the 350 to 450 range. Out of this 23, four of them led to containment failure, early containment failure.

MEMBER STETKAR: Hossein, please, please, this is a public record. Don't confuse the public record by saying 23 out of 300 or whatever. Twenty-three out of forty in the regime where it might have gone to containment failure completed. Twenty-three out of forty.

MR. ESMAILI: Yes, 23 out of 40. But what I'm saying is, out of this 23 that are in this range that could fail the containment, out of this 23, four of them, four of them actually led to early containment failure, meaning that, even out of this 23, not all of them are going to lead to containment failure because what is important is that -- and we already know that -- what is important is how much hydrogen you produce --

MEMBER STETKAR: Hossein, I'm trying to get simple here without getting into jargon. Out of the 40 cases that had the right characteristics, a stuck-open safety valve with more than 30 percent open area, there were about 40 cases, as I recall.

MR. ESMAILI: Right.

MEMBER STETKAR: Twenty-three ran to completion. Four of them went to an early containment failure. Why do we have confidence that the 17 that did not complete, 17 did not complete, that the same fraction, 4/24, of those 17 would go to early containment failure and not 17 out of 17 or 13 out of 17? That's what we're trying to get at.

MR. ESMAILI: That's right. It's still a very, very low number, in terms of the overall --

MEMBER STETKAR: If it's 13 out of 17, it makes it four times the early containment failure frequency. The risk might still be very low, but it's four times higher.

VICE CHAIRMAN CORRADINI: Hossein, I think what John is getting at, let me ask his question a little differently. What if -- you assume 17 out of 17. How does that change the uncertainty?

MR. ESMAILI: So you would have, if it's 17 out of 17, you would have 20 early containment failure, as opposed to -- of the overall, it's still we are really, we are really limited by how the safety valves work. The uncertainty is on that, not in --

VICE CHAIRMAN CORRADINI: I understand that. But I think another way to say it or a way to say it is to bound the uncertainty on the failure to execute, that's the bound.

MR. ESMAILI: Right.

VICE CHAIRMAN CORRADINI: Okay.

MS. GHOSH: Can I just, I might be stealing Hossein's thunder, but I do want to address this point of how many of the incomplete realizations may have gone to early containment failure. We've actually looked at that at this point because most of the incomplete realizations, as you can tell from Hossein's graph, this so far is only showing the integrated UA. We also did, we had 361 additional successful runs in the focused study --

MEMBER STETKAR: And 249 didn't succeed.

MS. GHOSH: That's right, so a lot of data points. And we've gone back and looked at those incomplete realizations, and most of them did run to first deflagration and the percentage that went to early containment failure at that first deflagration, which we already know, if you survive that first deflagration, then you survive to late containment failure, was exactly the same percentage as the completed.

MR. ESMAILI: So we can go to the next slide. This is coming on the next, at the next --

MS. GHOSH: Yes, I'm sorry to steal your thunder, but this was going and going. I just wanted to get that point out.

MR. ESMAILI: So this is, what the triangle that you see here, the triangles that you see here are the ones that traded the focused study. We are still in the same space. That means that I'm still producing this much hydrogen. The phenomenology tells me that I have to produce this much of hydrogen and be able to transport it to the containment. There is no, there is nothing that tells me that the cases that failed -- by the way, these cases that failed, the red ones, they failed after you had the first hydrogen burn. So this is a very important fact.

MEMBER STETKAR: That's no news for us. How come we haven't heard this since May of this year?

MR. ESMAILI: Because I think it was stated last time. I think it just didn't register. So I wanted to, so --

MS. GHOSH: We didn't add it to the report yet that you got, so it's going to be, it's new information that will be in the final but, unfortunately, that we hadn't included in --

MEMBER STETKAR: I mean, even orally, we haven't heard this insight.

MR. ESMAILI: Yes, I think that was --

MEMBER STETKAR: And, quite honestly, it does not come through very clearly with a whole mess of little different-colored triangles. It just doesn't.

MR. ESMAILI: Right.

MEMBER SUNSERI: So could you say it again then?

MEMBER BALLINGER: Yes, restate it for the --

MR. ESMAILI: All right. So this is, so when I talked about those high-level observations, I said I have to get this much hydrogen, I have to get to the first burn. So when you see -- the triangles were the focused study. We only focused on the cases where we had system depressurization, where we knew we are going to be in a sample space where we could potentially have early containment failure.

So the purple triangles are the cases that actually went to completion. There were 361 of them, the purple triangles from the focused study. I was actually thinking of changing it because everything falls on the same graph. So there were 361 -- it's explained in the report -- 361 of them that actually went to completion. Out of this 361, 17 percent of those led to early containment failure.

Now, we have the red triangles. The red triangles are also in the same sample space. They went actually past the first hydrogen deflagration because I don't care what happens after the first hydrogen deflagration because that is the one that determines whether the containment fails early or not.

Out of this -- let me see. Out of this 155 red triangles that I had, 15 percent of them also led to early containment failure. So whatever the code error or whatever that was producing this was a systematic error that was showing in the original UA that you have 10 out of, 17 out of 23 or here. But the important thing is that we have gotten more than 500 of the cases here that show that I'm producing enough hydrogen and only 17 percent of these cases have early containment failure.

VICE CHAIRMAN CORRADINI: So can I say it in less words? So you've gone through an event, you're looking at events as time passes and you've gotten through the event which you think --

MR. ESMAILI: Yes.

VICE CHAIRMAN CORRADINI: -- is the contributory to early containment failure.

MR. ESMAILI: Yes.

VICE CHAIRMAN CORRADINI: So just to be not mean to you all but comprehensive, it seems to me, if you ask Sandia, since they're the keepers of the thing, I know for every run MELCOR prevents an event summary sequence. I'm curious if you went further with an event analysis and find out what event do you get past before you crash, stop, fail, whatever the word you want to use.

MR. ESMAILI: This happens inside the core, as I said again.

VICE CHAIRMAN CORRADINI: I understand that, but what I guess I'm saying is, just so we're clear on this, if you get the valve failure, you get a release, and still it continues to chunk along, and then it fails to execute. Is it at the time or before creep rupture? Is it at or before accumulator dump? That would be another piece of interesting information to find out for later on.

MR. ESMAILI: We can make that clear. But was this, I'm trying to say if this information is helpful to you right now because now we have gone past, we have gone past when you have the first deflagration. And even those cases that failed, they did not fail the containment because they went past the first deflagrations, okay? So in other words, whatever there is, that systematic error that it's at 17 percent, whether it went all the way to completion. And, actually, this figure is very revealing because, in terms of overall hydrogen production, you know, because we have other uncertainties, we have rupture, pressure, that are just totally random, so I can sample this whether I am in the purple triangle or the red triangle. I can just sample this, sampling with the containment pressure, and I'm still going to be within that range that I don't think I'm going to get all that 17 cases lead to the containment failure.

This is one piece of evidence that we had. The other piece was the draft UA. If you remember, we did the draft UA. That one, we had a much, much better success rate and we had many more of the cases that we were in this space. But we were able to shake down the input, shake down the test, and get a much better success rate. Even those cases are suggesting that our early containment failure is in the 20 percent, 25 percent range.

So in other words, in other words, we are not expecting all the 17, let's say, of those cases to go to failure but a fraction of them. And just to drive this point, even if all the 17 goes to failure, it's still a small fraction. We are still, as I said, we have limited data on how this SV works. If I'm somewhere in the middle, it matters how I'm going to model this safety valve, I can increase that.

MEMBER KIRCHNER: Hossein, could I interrupt you here? Since I'm not immersed in this, I only, I've been to the subcommittee meetings, I've watched this and heard the presentations. My takeaway from this is the code is doing a good job at predicting in-vessel hydrogen. I don't see how I draw a lot of confidence about the deflagration time because that's an assumption in the code, isn't it? What's the assumption? When it --

MR. ESMAILI: No, hydrogen, so this is --

MEMBER KIRCHNER: You get a combustible --

MR. ESMAILI: Right. So this is --

MEMBER KIRCHNER: -- and then you assume there's a detonation source --

MR. ESMAILI: No. So you produce hydrogen, you produce hydrogen in-vessel so --

MEMBER KIRCHNER: You get a lot of good agreement on producing hydrogen, so that part gives me some confidence. Now, tell me about what confidence I should take on the vertical access when you said 17 percent.

MR. ESMAILI: So the hydrogen that produced in-vessel, the hydrogen that's produced in-vessel most of the time, it's either going through the rupture on the pressurizer relief tank going into the containment. What this is telling you is that, for all the cases that we had before, when there was failure to close, look at the time. We've got about one hour, right? I mean, one hour from the time that you produce hydrogen up until the time you have the first deflagration, but that wasn't enough time for me to vent all the hydrogen that was produced into vessel into the containment.

What this is telling you is that, not only am I producing more hydrogen, but I have more time to vent this hydrogen inside the containment. So by the time that an ignition source becomes available, and this ignition source, we have known ignition sources. It's either the hot gasses issuing from the pressurizer relief tank; hot gasses issuing from the hot leg; or whatever happens inside the cavity, if there are, you know, if it comes into the cavity.

And so once this happens, you have that ignition source. So this is telling me that this is how much hydrogen I have, some of it I have vented into the containment. Now my ignition source becomes available, depending on how much hydrogen I had at that time, what I could produce that could potentially fail the containment.

MEMBER KIRCHNER: Pardon my saying it like this, but what I still get from this is a reasonable systematic and repeatable estimate of hydrogen produced. What I have is tremendous variability when it detonates.

MR. ESMAILI: Yes, you have that. You have this. Some of it is driven by -- and I think we discussed this at the last, I think the --

MEMBER KIRCHNER: No, I understand all the reasons.

MR. ESMAILI: So there is variability.

MEMBER KIRCHNER: The simplistic takeaway for me is we've got a challenge to the containment, a high probability of an early failure.

MR. ESMAILI: This is actually, this is because we focused on that. We focused on the cases where we have high probability of failure. Remember, the high -- if you go back, Pat, to the previous one.

MEMBER KIRCHNER: Let me say it in a different way. So you made a lot of assumptions about the valve functioning, right? You got good reproducibility in the amount of hydrogen that was available as a source term. Now the question is where it is and whether it's a combustible amount of material or it will ignite, but you get a tremendous variability when it goes off, goes bang.

MR. ESMAILI: In the timing. In the timing of when that happens, and the conditions inside the lower containment, inside the upper containment, and how the ignition that's ignited --

MEMBER KIRCHNER: So you've done an uncertainty analysis, and my takeaway is there's a large uncertainty when the containment is going to be challenged. You're producing an enormous amount of challenges there.

CHAIRMAN BLEY: Well, I think they did these, you know this, they did these special cases to get these portions. But when they actually do a run, they're generating the hydrogen, it's leaking in the containment, and then, at some point in time, in that run, they know how much of it is in there, and then they get the ignition source and say is it --

MEMBER KIRCHNER: I understand all that. I'm just saying there's tremendous variability.

CHAIRMAN BLEY: So over a ten-hour period or so, so still pretty early.

MEMBER REMPE: Leave that slide. Were the code versions different on the slide with all the different dots? That one, yes.

MR. ESMAILI: We are running the same MELCOR 2.2 version for all of these cases. Again, we should have known. So previous slide tells us that I have 60-percent success rate in this range, right? If I go and run 600 cases, I'm going to have the same success rate because the errors were systematic. We could go back and fix them, but then that would put us in a success rate of 100 percent, and, you know, you have to go back and keep repeating these calculations. The question was is it worthwhile to do that, or do I have enough information to tell me that I have a low likelihood of early containment failure if the valves are behaving like this. And, again, as Tina pointed out, we have some uncertainties of how these valves work because of limited data.

So if I'm going from 62 percent failure to close an area of greater than 0.324 percent, if I'm somewhere in the middle, I would have many more early containment failures. So I'm really limited by my limited data and lack of knowledge on the safety.

But in terms of phenomenology, we have a better grasp of what happens. You know, we can reproduce this. We understand what conditions lead to less hydrogen, what conditions lead to more hydrogen, and what conditions lead to early containment failure versus late containment failure.

MEMBER KIRCHNER: Okay.

MR. ESMAILI: So this is what happens to the -- this is the containment pressure for all the cases, for all the short-term station blackout cases.

What you notice is that we can divide into three categories. You either have early containment failure. You have cases that you have early containment failure, as I mentioned. You have cases that we have late containment failure. These cases that are late containment failure are driven by, you know, core-concrete interaction, non-condensable gas generation, etcetera.

And then you have cases -- this mainly happens for beginning of the cycle, they have lower decay heat -- that you don't have containment failure within 72 hours. That does not mean that I'm never going to have containment failure. If I just increase this, I can, you know, it's going to be on the upward slope and then I can predict what the time would be to have the late containment failure.

The other thing I want to mention is that this is a short-term station blackout. We don't have igniters. But what we can see is that you see this pulses. Up to about 20 hours, we see these pressure pulses. This means that you get some of these cases led to containment failure, and we have that early containment. Some of them you still get hydrogen combustion. It's not enough to fail the containment, but you get periodic burns. At some point, we don't get any more burns here because we have produced a hydrogen. I'm actually producing a lot more hydrogen when I go ex-vessel compared to what I have in-vessel. But I just don't have the oxygen. I run out of oxygen inside the containment, so you see those pressure spikes are stopped. And so --

MEMBER KIRCHNER: After those early spikes, you don't assume any leakage into the containment. It's always over-pressurized so it's --

MR. ESMAILI: Yes, the containment, yes, the containment --

MEMBER KIRCHNER: So there's no oxygen source.

MR. ESMAILI: Yes, we don't have any -- yes. Even if there is a leakage, it's not enough oxygen. Just maybe a few more of these pulses, and then it would just die. But you're standing by our first insight that you can only get this thing, we can get a whole bunch of hydrogen into the containment. And if you can burn that hydrogen early enough, then you can fail it. If not, then the other ones are not, you know, which actually acting like an igniter because it's just periodically burning hydrogen as it's being produced. And so we don't get any subsequent failures.

So, hopefully, this answered, you know, some -- again, as I told you, we go back and the code is always under, you know, improvement. We can go back and look at these cases. At some point, we just did not want to go back to that particular version of the code, and it was not necessary for us to. You know, whatever conclusion we have, we have based on the cases that we have run.

VICE CHAIRMAN CORRADINI: So you didn't do it, but Tina did it, so I'll repeat it because I thought it was a wonderful volunteer. She's volunteering, I thought, to somehow take and generate a write-up that explains what we just went through in the last 20 minutes so that it's very clear as to --

MR. ESMAILI: Yes.

VICE CHAIRMAN CORRADINI: -- how you guys did the detective work in terms of what event you got past --

MR. ESMAILI: Right.

VICE CHAIRMAN CORRADINI: -- that allowed you to still feel that you're approximately in the same proportion of early failure.

MR. ESMAILI: Yes, we are going to explain that in the --

VICE CHAIRMAN CORRADINI: And since you're doing that, it sure would be nice if you went further and did a little more detective work to figure out what events you further have so that you actually can maybe analyze failure to execute downstream because I just have this funny feeling, I can't prove it, that when your accumulators discharge -- MELCOR is not a re-flood heat-transfer computer model so that when you dump a bunch of water in, you've got a blazing hot set of hot structures that has a very difficult time coming to conclusion of an execution. So my guess is it's somewhere the time when you're starting to depressurize and dump accumulators is where a lot of these failures are occurring. That's just a guess. But looking at an event analysis, as you've already done a bit, would be worthwhile.

MR. ESMAILI: Yes. Some of those cases that you saw that we are producing a lot of hydrogen, those cases, those cases are the system is depressurizing. So as the system is depressurized and the accumulator continues to inject. But I want to again emphasize is that this particular containment is very, very sensitive to how much hydrogen. So in other words, if I can delay, if I can delay the combustion of the hydrogen by that time, I still get the burn. But I have burnt enough hydrogen that, even if that accumulator comes a little bit later and produces more hydrogen, it's not going to, just like these pressure pulses are not going to fail the containment.

VICE CHAIRMAN CORRADINI: I'm not disagreeing with you. I'm just simply saying that, from the standpoint of understanding the root cause of failure to execute, that would help. That's all.

MR. ESMAILI: Yes.

MEMBER KIRCHNER: And could you just summarize what was the major reason for such a tighter convergence with the MELCOR 2.2 versus 2.1?

MR. ESMAILI: What slide there?

MEMBER KIRCHNER: Pick any one. Seven.

MR. ESMAILI: Okay. Yes, let's go to seven. So this is, again, this is the safety valves. You see the red?

MEMBER KIRCHNER: No, I'm not talking about the codes. I understand. I'm just trying to understand or see if you understand why 2.2 is getting a tighter --

MR. ESMAILI: No, but 2.2 -- okay. Maybe I can answer you.

MEMBER KIRCHNER: -- a tighter spread than 2.1.

MR. ESMAILI: 2.2 -- well, because, first of all, we have less, we have less points in there. Go back to the SV study. That --

MEMBER KIRCHNER: The trend I see in the points you have shows a tighter result.

MEMBER STETKAR: But isn't it, I mean, what you're missing here is they ran the April version of the study, April 2016 version of the study, which had the left-hand bar performance of the safety valve, they ran that study using MELCOR 2.1. They ran the right-hand bar with MELCOR 2.2. So it isn't completely a MELCOR versus MELCOR. It's more safety valve versus safety valve.

MR. ESMAILI: But there is one thing, and Larry mentioned it when he was here on April 18th, that they said there was actually, in MELCOR 2.1, a draft UA, even though the safety valves, but what we had is that we were not quenching properly. So it was possible for us, even after accumulator injection and the reflux, we were producing more hydrogen.

In this new UA, after the accumulator injects, it properly quenches, and we don't get that much hydrogen. But what this figure is trying to show you is that, again, it's up to the time of first deflagration that --

MEMBER KIRCHNER: Yes, but this was my point earlier. So what in the model has changed that you described it that you're doing quenching better and, hence, you don't get as much hydrogen? I understand -- what's different in the codes, not just the results?

MR. ESMAILI: This was -- there were a couple of errors, if you remember. We came back on April 18th and we said that, first of all -- no, it was April 18th that Larry came here and gave a -- yes, it was the springtime. So the orange circles, the draft UA on MELCOR 2.1, they had a couple of issues. I think they have it in one of the -- first of all, we were not quenching, so some of the cases we were not quenching, so they were still producing hydrogen. So we were producing more hydrogen. The other one was that, as it was coming, we were applying a dry-up heat flux that we should not be applying to what was on the core plate. So once that one fixed, we went to MELCOR 2.2 and reproduced.

But the point is that, even with those errors, we are still in the same sample in the same region because what is important is how much hydrogen you produce by the time of first deflagration. And so this figure was very telling, and, as you can see, yes, you are right, we are getting tighter on the blue ones because after hot leg failure we are not producing anymore hydrogen and this is clear. Again, you know, we could go back and --

MEMBER KIRCHNER: No, I'm not asking that. Just a clarification. Thank you.

MS. GHOSH: Okay. So we're going to shift gears now. Hossein, we don't have time today to talk about all of the results in our very thick report, but we just picked out a few to highlight. And the containment, what we call the horsetails are the distributions for the containment pressure, pressurization, and failure is one of them. And I hope you have that figure in mind.

VICE CHAIRMAN CORRADINI: Well, we just wanted to make sure we gave ample time to Hossein.

MS. GHOSH: If you want to keep going with him, that's fine with me. But we're going to switch now to the off-site consequence portion of the analysis that comes out of the MACCS code, and I hope you have that containment pressure curves in your mind still because it helps explain one of the interesting features of the consequence results.

So I've had a lot of people come to me and say what is this, this is a complimentary cumulative distribution function, which most of the time doesn't look like this where you have this big hump in the middle. And the reason that our -- in this case, we're graphing the population-weighted latent cancer fatality risks at different distances from the plant. So these are annular rings that are centered on the plant. You see the red line is the zero to ten miles, and the other ones are labeled.

And these are the means, the distribution of the means over all the weather trials. So, basically, these are --

CHAIRMAN BLEY: Now, can I stop you right there?

MS. GHOSH: Yes, go ahead.

CHAIRMAN BLEY: Because we didn't go through the Level 3 analysis, I don't think, in a subcommittee, but we did go through, to some extent, the Level 3 for the Level 3 PRA, which the words and things seem very similar to me. And we had a problem over there, which maybe you can explain to me right now. When you say population-weighted latent cancer fatality risk, is this the expected number of deaths over a lifetime following an accident? Is this the expected dose? Is this expected cancers per year? What is this?

MS. GHOSH: So this is the -- okay. This is conditional on the event occurring.

CHAIRMAN BLEY: Given the accident, this is what?

MS. GHOSH: Yes. Given the accident, this is the risk of, technically, it's population weighted, but you can think of it as an individual who lives in this annular ring around the plant, their risk of incurring a latent cancer fatality due to the accident having --

CHAIRMAN BLEY: Over their lifetime.

MS. GHOSH: Over their lifetime, yes.

CHAIRMAN BLEY: So this is the individual likelihood of a person. It's not the expected number of deaths, it's essentially the probability of one person getting a latent cancer event or a latent cancer fatality? A latent cancer fatality?

MS. GHOSH: Fatality, right. And --

CHAIRMAN BLEY: With or without treatment.

MS. GHOSH: -- it gets a little tricky because you can also count up the numbers, which can end up being less than one, and then divide by the population in that ring that you're looking at.

CHAIRMAN BLEY: I'll tell you what, when I read chapter six, all I have notes all over it saying exactly what is this. So what you just explained to me isn't explained in that report, near as I can tell.

MS. GHOSH: So we should spell it out --

CHAIRMAN BLEY: You know, these are risks, but they can be almost anything, and you have to tell us what they are.

MS. GHOSH: Okay, yes. Thank you for the comment.

CHAIRMAN BLEY: In the Level 3 report, there was great confusion, and there was expected deaths mixed in with other things.

MS. GHOSH: Okay.

CHAIRMAN BLEY: So this isn't expected deaths within the population. This is probability per person over their lifetime following this one exposure.

MS. GHOSH: Yes, that is, that is --

CHAIRMAN BLEY: Do you know if they modeled treatment or not?

MS. GHOSH: Oh, okay. Well, this is a very simple calculation, and I might call on --

CHAIRMAN BLEY: The answer could be either way, depending, even if it is simple.

MS. GHOSH: We add up all the organ-specific doses that the population got, and those doses get multiplied by a cancer mortality risk given that dose. And we have distribution --

CHAIRMAN BLEY: Given treatment or without treatment?

MS. GHOSH: That's a complicated question.

CHAIRMAN BLEY: It's a simple question. The answer might be complicated.

MS. GHOSH: Yes, I don't think we assume treatment but --

CHAIRMAN BLEY: But you don't know, and I don't think it says here because it doesn't even tell me that this is what this.

MS. GHOSH: I don't think we get into whether they were treated or not. Yes, I see my colleagues are shaking their heads.

CHAIRMAN BLEY: It's built into that number you use to translate from one to the other. Hi.

MR. COMPTON: Hi. Keith Compton, Office of Research. I will say this --

CHAIRMAN BLEY: It's working.

MR. COMPTON: The short answer to that is that I don't know the precise answer. Like you said, it would be baked into whatever the mortality risk coefficient would be, yes.

CHAIRMAN BLEY: You guys ought to know the answer to that question.

MR. COMPTON: We need to go back and see where the --

CHAIRMAN BLEY: Okay.

MR. COMPTON: -- stem from. For acute health effects, that is a consideration because you have to make an assumption about what level of treatment is given. But I'll take that as an action to go back and find out what the underlying assumptions of that are.

CHAIRMAN BLEY: For different kinds of cancer, it makes a big difference.

MR. COMPTON: Right, right. So you do see there's a distinction between incidents and fatalities, so, yes, I'll take that as an action to go back and find out.

MS. GHOSH: Okay. So --

CHAIRMAN BLEY: Not so complicated, but thanks.

MS. GHOSH: So these are the CCDFs, the complementary cumulative distribution functions, at those annular, for the populations in the annular rings around the site. And the reason that you see this bimodal distribution where you have about 13 percent that's spread out in the upper left corner and then you have three orders of magnitude where nothing is happening and then you get onto a new curve to the right has to do with the fact that in about 13 percent of our cases we don't have containment failure.

So most of those were from the beginning of the refueling cycle cases where you saw in the graph Hossein showed those yellow curves that are still going up at the end of the 72-hour simulation time and have not failed containment yet. You get some very low risks just from leakage. And then, if you do fail containment, then you end up on the part of the curve that's over to the right that kind of strikes beyond the ten to the minus five number at the bottom. And there were a handful of middle of cycle cases that also hadn't failed containment by 72 hours, so it's primarily the beginning of cycle cases and then a handful where the middle of cycle cases hadn't failed yet.

MEMBER STETKAR: Just for the benefit of folks that haven't been around, the report currently does better at trying to explain this than it did before. There are still some cases where there are statements saying, well, the population latent cancer fatality risk ranges from ten to the minus three to ten to the minus tenth, which, on this plot, that's true and that, you know, the observation is the further you are away from the plant the lower the risk is. Well, that's true if you're on the left-hand side of the curve, not so much if you're on the right-hand side of the curve.

So it's a pretty subtle but important when you're interpreting the results to kind of explain it pretty clearly, pretty much as clearly as you tried to do orally today.

MS. GHOSH: Yes. And, certainly, the risk curves with the annular rings, they're pretty tight together, in fact tighter together than we had seen in some of the past studies when you get out to the part where you have failed containment. And we did try to analyze why that was the case, and there is some discussion in chapter six on that.

But in terms of, you know, the overall range of, you know, health effects, again, these are the conditional risks, so they're still fairly small, even in the cases where you had an early containment failure. And we tried to fill out, add some data points in that regime, as well, with that focused safety valve study where we did add some health consequence results in that appendix.

MEMBER KIRCHNER: One more time. So in the middle ranges, when all the curves collapse together, that's simply because the release is so large that it exceeds the threshold for saying that the persons at risk of getting cancer.

MS. GHOSH: Yes. Actually, maybe it would be better to show no lines in that because there's a discontinuity because really there's two curves. There's one set of curves where those 13 percent of the cases where we didn't get containment failure and we have very low risks, and then there's nothing in the middle. And then if you do fail containment --

MEMBER STETKAR: The probability density functions, it would be clear that there's two humps and that there's nothing in between.

MS. GHOSH: There's nothing in the middle.

MEMBER STETKAR: But as a CCDF, it's saying what's the probability that it's this amount or greater, so you get rid of the first set and then it just hangs there.

MEMBER KIRCHNER: Oh, I understand it, but it might be counterintuitive to the public.

MEMBER STETKAR: Oh, it is.

CHAIRMAN BLEY: But the CCDFs have become the language of this kind of stuff.

MEMBER RICCARDELLA: Well, why did you choose not to plot it as probability density?

MS. GHOSH: Well, I guess we hadn't traditionally done that. I suppose if there's interest in doing that we could but --

MEMBER STETKAR: There are benefits and drawbacks from it. The problem is that the left-hand side of this, you get this really, really broad kind of little low mound of thing and then, over on the right-hand side, you get something that looks like more of a bigger hill, and those can be misleading.

CHAIRMAN BLEY: Well, they can, but at least you get a sense that the one is very unlikely and the other one is still unlikely but not nearly so unlikely. The text talks about the bimodal nature, but it talks about it as if you were actually showing density functions, which would have made it easier to understand that part of it.

MS. GHOSH: And this is just a very high-level summary of the off-site consequences. Very similar to what we have seen in past studies. Even when we get an early containment failure, the early fatality risks are negligible and, essentially, zero. We get, actually, identically zero for the cases where we didn't fail containment early. And in those three realizations, in the four realizations that we did, out of those, three of those had a number of the weather trials, not even all the weather trials, where you could compute a non-zero number. So we continue to say there's, essentially, zero individual early fatality risk that was calculated.

For the latent cancer fatality risks, they're small, even in the cases where we had early releases to the environment. And they're generally dominated by the intermediate and long-term phase exposures compared to emergency-phase exposures, although we do have a minority of realizations where the emergency phase exposures are more important. And we didn't show the regression results for the MELCOR results, but you see that the things that are important to the source term also pop up as important to, they translate to being important to consequences, as well.

Hands down, the most important thing for the latent cancer fatality risk was where in the refueling cycle you happen to be when the accident occurs, and this really has a dual effect on the off-site consequences. It affects the source terms because of decay heat.

And then, in terms of health effects, you have also the fact that you have an ingrowth of the long-lived isotopes, such as cesium-137, which is a second level of effects for the health effects. So that makes sense.

And then for the cancer fatality risk factors, I mentioned that those are calculated by organs, and we have eight sets or organs. The residual organ is kind of a catch-all for all the ones we don't explicitly model, and it's an important one because cesium as an external ground-shine dose contributor delivers a lot of dose, for example, to the pancreas, the soft tissues, and so it makes sense that that shows up as important.

The lungs, again, because we have some cases where the emergency-phase risks are important, the lung factor makes sense because you're getting inhalation doses from the emergency phase. Colon is another soft tissue.

Containment rupture pressure. I think that's self-explanatory. That affects both whether you might get early containment failure. If you sampled a lower rupture pressure, you're more likely to get the early containment failure from that early deflagration of hydrogen. And even if you get into the late regime, you're on those gradual pressurization curves, and it's beneficial to fail later because you can have more settling of radionuclides before the containment fails.

CHAIRMAN BLEY: Now, you do shine dose and inhalation dose and you make some arguments -- I think it's in this study and probably in the other one, too -- that you don't have to look at ingestion dose because food comes for all these funny places. But you just ignore it then, and it seems like you ought to at least have a calculation done that assumes you get all your food from this area and would it be a big deal or not a big deal so one could at least tell that.

MS. GHOSH: We have considered the ingestion dose in other studies. For example, some of the reg analyses we did --

CHAIRMAN BLEY: Yes, I know.

MS. GHOSH: -- such as the filter --

CHAIRMAN BLEY: It's just here the argument is a one-sentence, well, people won't eat this stuff, you won't . . .

MS. GHOSH: Yes, maybe that's satisfying. Maybe it would be better just to say we don't, state that we don't include it.

CHAIRMAN BLEY: Well, you do say that.

MS. GHOSH: Yes. I think the past studies have shown that food pathway is not a huge contributor, actually, to the --

CHAIRMAN BLEY: It would be better to do a sensitivity case and show that, if, in fact, that's true, to show that than just to ignore it because it leaves the question open of how big a dose could it be? What if I did eat this stuff? What if I had trouble getting out of the area and I had to eat stuff that was outside or try to decon it on my own or something. But it's not a very convincing treatment. It's a non-treatment that kind of wishes it away.

MS. GHOSH: Okay. Number of safety valve cycles. I think we've talked a lot about why that's important, so I won't say anything more about that.

Next slide, please. So we wanted to just wrap up with some of the lessons learned from this study. And the handful of bullets I have are all kind of related. And, you know, one of the things we've learned in the past several years, it's hard to do a single best estimate severe accident simulation just because it's a very complex system, there are a lot of synergistic effects, there are a lot of threshold effects, and it's hard to kind of pick a best estimate simulation.

Now that we have included the uncertainties and explicit uncertainty analysis as we're doing this, we find that it's been very beneficial and it's definitely an iterative process. We've never gone through the first time through and said this is our final analysis. We've had to repeat it many times and I think for good reason. And you really do need kind of a team of both subject matter experts who understand the phenomenology and really physically what's going on, as well as kind of the UA folks who can tell a part of the statistical story. And we've tried to use both the statistical methods, you know, complimented with the phenomenological explanations to be able to tell the story.

So we didn't talk a lot about the regression analyses we did, but the statistical regression analyses are very valuable because they tell us from a statistical standpoint what is showing up as important. And then we can -- and if you do enough, you know, variations and runs, you can kind of pick out individual cases that the subject matter experts can really study in detail and help explain what's going on in those cases to be able to show phenomenologically what's causing variations in your accident progression and releases. So we found that to be very valuable.

Next slide, please. And, again, considering uncertainty from the beginning of the project, I think we touched on this a little bit earlier, it's helped us to sharpen our pencil in areas that matter to the outcome. And this is just one example. In last year's draft uncertainty analysis, we didn't know a lot about what the safety valve open-area fraction ought to be if it failed to close, and we kind of said, well, we'll assume a uniform distribution. Well, it turns out that that open-area fraction distribution is very important to the outcome of the analysis. So we decided to go back and see whether we could collect some more information, and we talked to subject matter experts who know valves better than we do. We re-evaluated the very limited operating experience information that we did have, and we found that we were able to come up with something that was, we felt was more defensible than just it could be anything between one person and one. And it does have an impact on the analysis, so I think it was worthwhile to go back and do that.

The other thing is that, again, with these complex systems, it's important to have an integrated modeling perspective. And just as an example, you know, for the MACCS model, we had assumed a seismic initiator. How you get into the short-term station blackout situation in the first place is a very bad day, and, you know, based on the PRA information that we have, it seemed that a seismic initiator was probably a high chance of how you get to this very bad day. And so we thought carefully about what that would mean for evacuating people from the plant.

So that's just one example of we tried to take an integrated perspective. In this case, we assumed that all the bridges would be unusable and then modeled the evacuation network and calculated the evacuation times based on that all the bridges are just not usable from the impact of the seismic event. So that's just one example.

And I think I'm going to turn it back over to --

CHAIRMAN BLEY: Well, before you turn it over, I stumbled across a sentence that I need your help with in section 6.3.1 of your report. It's talking about these special realizations that give you information on cesium and other things, and it says that it should be noted that realization 36 uses a mock MOC inventory and, even though its release fraction is the largest, the highest cesium, realization 395 releases a larger total mass of cesium. How can you get more cesium out of a case that has a smaller release fraction? I don't get that.

MS. GHOSH: Okay. So the release fraction is what it sounds like. It's the fraction of the inventory that you had in the core at the time of the accident.

CHAIRMAN BLEY: Yes, that's where the cesium lives, too.

MS. GHOSH: That's where the cesium goes, right. And the cesium inventory steadily grows from the beginning of cycle to the end of cycle.

CHAIRMAN BLEY: Okay. So one of these cases it's growing outside? Go ahead. You explain it to me.

MS. GHOSH: So the end of cycle case has maybe, has more cesium in the inventory. So 75 percent of more is more. So we were always, for the MELCOR analysis, we're always looking at the fraction of what's in the core. But you have more in the core at the end of cycle. So you can have a smaller fraction at the end of core that is more than a higher fraction in the middle of cycle.

CHAIRMAN BLEY: Okay. That makes sense. I mean, the sentence isn't well explained.

MEMBER STETKAR: That's why Hossein kind of showed the red, yellow, and blues, and it said, well, from his part of the world, blue and red didn't make too much difference whether you're in the middle or end of cycle because, no, from thermal hydraulics because the decay heat is about the same. Yellow was much different. Tina had one bullet that said, oh, one of the most important parameters for latent cancer effect is the time in cycle, and that's because of that inventory.

CHAIRMAN BLEY: Well, but it's certainly a balanced --

MEMBER STETKAR: Oh, yes.

CHAIRMAN BLEY: It's the product of the two that gets you where you're going. Okay.

MEMBER KIRCHNER: So you have this holistic result. What, in your mind, have you learned from this in terms of improvements for MELCOR and MACCS?

MS. SANTIAGO: I think we've had a number of discussions, and I think we had Hossein come in about a couple of months ago talking --

MEMBER KIRCHNER: I'm not trying to reopen that, just a summary.

MS. SANTIAGO: For the MELCOR in particular --

MEMBER KIRCHNER: What would you look to improve in those models? What had the biggest impact in the models versus the output, the results?

MR. ESMAILI: From my perspective, the more calculations you do, the more you expose where you could potentially improve the code.

MEMBER KIRCHNER: And you've done that, so I'm trying to get to that --

MR. ESMAILI: So, yes, when we went from the draft UA, as I explained, when we went from the draft UA to this current UA, we did many, many, many code changes. This was some of the cases that really showed that, yes, the model that we had for quenching was not working properly, you know. The model that we had for the dry-up model was not working properly.

These were coming out of other calculations, just to be honest, but there were more subtle things. So when Larry, when he was here, when he goes and looks at these things, it's not that we are going to totally forget about, you know -- there are cases where, you know, again, with these core relocations, sometimes it's logic based, so it's how you want to transfer this particular debris from this particular -- now we have many components. We have molten material, we have particulate debris, we have material that has frozen over some -- so you come up with some, in a cell, you come up with a situation where it doesn't make sense, the logic does not make sense, and this is something you have never thought about. Then you say, oh, wait a minute, I cannot have a case where I have, you know, like a solid rock sitting on top of a particulate debris. So these calculations, when we do these calculations, these failures, etcetera, help us go ahead and improve upon our code.

And if I go a little bit further, you know, I think our success rate is improving. So when we did the calculations back in 2015, our success rate was 84 percent. I understand that, you know, it's still not 100 percent because 17 of those cases, but from 2015 going to 2017 our success rate is improving. So the code is actually becoming more and more robust until we actually have another input that we have to go back and look at those things.

So this is helping us in a lot of ways and, not only this, we have about a thousand code users throughout the world from 28 countries. So anytime they do calculations, they report problems. What we learn here, we report back to them. We give them a different version.

MEMBER MARCH-LEUBA: So is it safe to say that, at the end of this exercise, you have a code that is good enough to run this exercise, not a list of improvements? You already have the code --

MR. ESMAILI: Say that again.

MEMBER POWERS: Many, many jobs in this world. Once you've done it, you know how to do it.

MR. ESMAILI: I just don't want to be very defensive. I was accused yesterday of being very defensive about --

MEMBER MARCH-LEUBA: The purpose of this exercise was not to generate a list of things you want to improve in the code but to generate a code that is good enough to run this exercise, and you already have that.

MR. ESMAILI: And we already have that. And, again, again, I hate to say this again, but I don't want to go back to these failure cases, but, you know, but people, not everybody goes through this level of detail to run 600 calculations. People usually do a few calculations, plus sensitivity calculations. They are able to go back and check. So the code can overcome some of these failures. It's just that when we hit something that's physically unreasonable, and I actually had one case a couple of where the time and temperature failure was not working properly. This was for the cases that I had this heat-up going on for days and days and days and suddenly failed. So there were actual errors.

But, yes, you are right, the code becomes more and more robust for future use. We are able to run this scheme for longer and longer time. There was a time that, you know, we were running these kinks for about 24 days and said, okay, that's enough. Now we are running it for three days. Level 3 is running it for seven days. So, you know, we are pushing the envelope on how --

MEMBER REMPE: I guess I was wondering if this integrated sensitivity analysis has led you to determine that some of the input parameters might have a more significant effect so that you might want to improve models in the future and are there some examples like that you want to cite?

MR. ESMAILI: One of the things that came out and, again, I had to go back to the failures. So one of the things that came out, again, when the code becomes challenging, we're at low pressure, we have a lot of code that will be going into one cell and you've been into this MELCOR map crosswalk and see what happens. So we have situations where one core cell is not much material. You know, there is maybe less than a percentage of the core cell that's available for me to just put in water and steam through it.

So part of this exercise is telling me what am I going to do in those cases? Should I forget about that material and move on? Because those are the cases that the code really tries to go to very, very smaller time steps.

So we are improving the models by making the code smoother so we can actually do more of these calculations in a more reasonable amount of time. Does that answer your question about how these things --

MEMBER REMPE: Well, it's not exactly the answer I wanted, but it was the question --

MR. ESMAILI: So tell me what answer you wanted, and I'll give that.

MEMBER REMPE: I was hoping you might say that your decision to emphasize the liquefaction might have stemmed from this because of the sensitivity analyses where it came out to be, you know, if there were similarities in the sensitivity analysis that came out to be important, you might decide to refine that model a bit. That's what I was kind of expecting to hear.

MR. ESMAILI: Right. And, again, to be honest, not everything, you know, again, there are some of these cases that Larry mentioned that and I gave you that that we knew that there were these models in the code that was varying the code from early 90s that never worked, and we are resurrecting them. Yes, some of this had to do with what you're suggesting, but this was not the only input into the code --

MEMBER REMPE: Not the only one, but maybe it highlights --

MR. ESMAILI: Oh, yes, absolutely.

MEMBER REMPE: -- it's become more important to maybe fix this --

MR. ESMAILI: Absolutely, yes, yes.

MEMBER REMPE: -- because in the past, oh, it doesn't matter that much or something and it wasn't a higher priority. That's what I was wondering.

MR. ESMAILI: Or it was difficult to do.

MS. SANTIAGO: Well, we understand in different designs what you need to look at closer.

And so a lot of what we learned from this analysis, as well as some of the prior ones, we're implementing in the Level 3 PRA. What metrics should we report? How do we communicate clearly?

So we've learned a lot. The organ dose coefficient factors we might need to update in MACCS because we may want to isolate the pancreas or something and not just have it grouped.

MEMBER MARCH-LEUBA: At the end of the day, what was the largest change that you made between the draft and the current? That slide, the top right figure right there, is what you assume for your safety valve, the yellow and blue. And I have to say that we don't have any basis for yellow or blue. Blue looks more reasonable. If you are going to use the one with the two column, it's clearly the biggest effect. You can ignore everything in the code. It's what you assume for the safety valve.

MR. ESMAILI: Yes, and it's very intuitive, right, because that's the only place where hydrogen is coming out of the vessel. You know, that's where --

MEMBER KIRCHNER: So is Research proposing a program to, an experimental program to get data on safety valve performance?

MR. ESMAILI: Not necessarily.

MS. GHOSH: I think if somebody wanted to do that, that would be very satisfying if we could collect more information. From NRC's perspective, all of these things, all of the outcomes that we've come up with are still showing very low risk outcomes. So the question is where does the motivation come from to spend more money to keep looking at this.

MEMBER MARCH-LEUBA: The first time I saw the safety valve failure rates from the LERs, I would expect that most of the failures to close were leakage, as opposed to one-third of the valve not closing.

MS. GHOSH: Right, right, right.

MEMBER MARCH-LEUBA: And so even on the blue line, we are underestimating. It will be even lower if we knew this information. Most of the failures are going to be leakage.

MR. ESMAILI: So the other part is that, you know, this is, as far as igniters are concerned, even four is one too many, right? I mean, so, in other words, you still want to prevent any hydrogen burns. So whether it's 4 out of 600 or 100 out of 600, you know, what you want to do is that this is telling us that this is what you have to do in the short time, make the igniters available, you know. And so I don't think safety valve is going to necessarily change that aspect of the problem.

MEMBER KIRCHNER: So were plants going to an uninterruptible power supply for igniters as a mitigating feature?

MR. ESMAILI: I don't want to get into the operations. I think that part of the FLEX is that you would always have batteries. I mean, even as GSI 189, you know, some of these plans, they already have dedicated AC power to power up these igniters and they're going to have more success with the FLEX, I suppose.

MS. GHOSH: Can I just answer? I think two of you asked what did we learn also from the MACCS side. If you want an example from our side, I think, you know, Pat mentioned we want to take a closer look at some of the organs that matter a lot for all the scenarios we've looked at. We know cesium doses, external cesium doses to soft tissues are important. We could probably do better in modeling that.

With the MACCS code, and I know we've had past presentations, maybe years ago at this point, on improvements that were made at the start of SOARCA, you know, for MACCS. That was based on kind of an expert panel that reviewed the code and, you know, made some recommendations on what we could do.

But more recently, the results of our past and the first two uncertainty analyses kind of drove some of the input improvements that we've made, basically from Peach Bottom to Surry and then from Surry to Sequoyah. And I'll just give you one example. The dry deposition velocity distributions, which are based on the size of the particles that are traveling, they were originally very, very wide. They spanned three orders of magnitude because they were taken from an international expert elicitation on non-site specific parameters for off-site consequence analyses from the mid-90s. And, generally, that was referred to, well, that's kind of the best that we have. But that was driving a lot of our uncertainty in the Peach Bottom results.

So when we went back and looked at what was the basis for the experts coming up with their distributions, we realized that they were taking into account the weather variability, in addition to the state of knowledge or epistemic aspects of the, you know, what is the true velocity for a given size particle as it's going a certain speed or whatever. And when we realized that, you know, we thought about it and our experts in this area came up with a revised distribution to reflect that we actually take weather variability into account when we then apply that velocity.

So that's just one example of, you know, these studies help us hone in on this is showing up to be very important, can we sharpen our pencil and do better at describing this parameter of uncertainties, and that's just another example.

MS. SANTIAGO: I think it also told us that it's really site-specific information that makes a difference in these analyses, and so weather being one of those. And I think, because of a number of different questions we've gotten from the Committee members, we've also improved our discussion on emergency preparedness and things like that. So that's another thing that I think we've improved since the original SOARCA analyses.

MEMBER RICCARDELLA: FLEX is real. It's implemented or being implemented in most plants. Are there any plans to look at, to re-look at the effects on this study of having FLEX equipment in place?

MR. ESMAILI: I guess not this one. This was unmitigated phases.

MEMBER RICCARDELLA: I understand that.

MR. ESMAILI: So we did some sensitivity to see if you have the igniters available, of course you are going to prevent. But as far as our insights are concerned, yes, it's not going to change, it's not going to change the conclusions of our --

MEMBER RICCARDELLA: Of an unmitigated study but . . .

MEMBER STETKAR: This is not a risk assessment. This is a stylized analysis of one specific sequence, a short-term station blackout. That's all it is. It's nothing more and --

MEMBER RICCARDELLA: Oh, I thought it said long term.

MEMBER STETKAR: So Level 3 PRAs should look at stuff like this. We've got a couple more slides here, and we're kind of running late on time here.

CHAIRMAN BLEY: Before we would start trying to whittle down the consequence numbers, I'd rather see us be systematic about the modeling uncertainties and trying to deal with them to see how --

MEMBER STETKAR: And there's things on the consequence analysis that we haven't discussed. They didn't treat Chattanooga very well or evacuation in

Chattanooga, for example. They treated evacuation within ten miles.

You know, so there are pluses and minuses that you could argue about, you know, in this whole, even within the context of this focused little study. It accomplished what it wanted to accomplish, an integrated assessment of MELCOR and MACCS challenging hydrogen releases in a particular type of containment.

MS. SANTIAGO: And to do that study, it took a lot of different folks with a lot of different technical disciplines. And I want to thank our program office staff, as well as our Sandia National Lab partners, for working with us diligently over the last 18 months. And I invited them today, a number of them. Andy Hahn, who is the project manager for the Sequoyah site, he got us out to the public meeting and we had a successful public meeting about a year and a half ago. Dr. Salman Haq organized it. I see Ed Roach and Todd Smith from our interoffice who helped diligently answer some questions that Dick Skillman asked us on emergency preparedness. And I want to thank Hossein, Casey Wagner, a lot of folks from Sandia, Randy Gauntt that worked on the MELCOR model and improved it. Kyle Ross, as well.

So this list, again, you've seen Dr.

Bixler, Keith Compton. But we couldn't have accomplished this particular technical analysis, as complex as it is, in the 18 months without this cadre of folks, and I really am honored to work with them.

The last is just a summary saying that we believe we met the objectives for the pilot analyses. And, John, I think you mentioned that. And I do think it was a wonderful recommendation that the ACRS gave us to do the Sequoyah analysis as an integrated analysis, doing the uncertainty analysis alongside of the deterministic analysis. It really gave us a lot of knowledge, and it helped us identify what parameters were important and most important. I think we've already talked about the improvements in the modeling capability over the last number of years.

And I want to thank each and every one of you for the challenging questions you've asked us in every meeting we've had with the subcommittee, as well as today. And I think it's only going to improve the documentation and the discussion in these reports. So it's a heartfelt thank you for listening to us over the years and giving us several recommendations.

And that concludes the presentation by the staff.

MEMBER STETKAR: Thank you. Any of the

members have any kind of final questions? If not, are there any, is there anyone in the room who would like to make a statement? If so, come on up to the microphone, identify yourself, and do so. Seeing no rush to the microphones.

If there are any members of the public on the bridgeline who would like to make a statement, just please speak up, identify yourself, and make a statement.

MR. BROWN: It's open.

MEMBER STETKAR: Okay. Any? Apparently not. Again, staff, thank you very much. You crammed a heck of a lot of material into the hour and a half, plus nine minutes, that we've had. And with that, Mr. Chairman, it's back to you.

CHAIRMAN BLEY: Thank you very much. At this point, we are going off the record for the week.

(Whereupon, the above-entitled matter went off the record at 2:38 p.m.)

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UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

State-of-the-Art Reactor Consequence Analyses (SOARCA) Project: Sequoyah Integrated Deterministic and Uncertainty Analyses

Full Committee Briefing
November 2, 2017

Patricia A. Santiago, Chief, Accident Analysis Branch
Hossein Esmaili, Fuel and Source Term Code Development Branch
Tina Ghosh, Accident Analysis Branch
Division of Systems Analysis
NRC Office of Nuclear Regulatory Research

Outline

- Overview and Objectives
- Uses of SOARCA Modeling
- Short-Term Station Blackout Analyses
  - Severe Accident Progression Observations
  - Insights on Hydrogen and Containment
  - Offsite Consequence Analysis Summary
- Lessons Learned
- Summary

Overview and Objectives

- SOARCA goals and objectives
  - Develop body of knowledge on the realistic outcomes of severe reactor accidents
  - Incorporate state of the art modeling (MELCOR/MACCS)
- SRM SECY-2012-0092
  - Limited to station blackouts (SBOs)
  - Focused on issues unique to ice condenser containment and hydrogen challenges
- SOARCA Sequoyah NUREG/CR report due to the Commission on November 30, 2017

Uses of SOARCA Modeling to Support Agency Activities

Technical Bases for Regulatory Framework

- MELCOR and MACCS analyses BWR Mark I filtered vent analysis and CPRR (Tier 1 – 5.1)
- Other containments and hydrogen (Tier 3 – 5.2 and 6)
  - Sequoyah SOARCA analyses supported closure of these items
  - SECY-15-0137 and SECY-16-0041
- Expedited spent fuel transfer (MACCS)
- Emergency preparedness – decommissioning exemption requests
- Uncertainty analyses determine most influential parameters
- MACCS parameter guidance supports new and advanced reactor designs, knowledge management for severe accident analysis

Licensing and Environmental Review Uses of MACCS

- Environmental assessment and impact statement analyses
- Waste Confidence technical bases for spent fuel fires and D/FGEIS
- Hearing support for technical analyses (Indian Point; Seabrook)

Uses of SOARCA Modeling to Support Agency Activities and Knowledge Management

<u>Insights for Emergent Issues with MELCOR and MACCS</u>

- Supported NRC incident response to Fukushima event
- Fukushima Forensic Analysis to better understand BWR accident progression

<u>Knowledge management for Severe Accident Analyses</u>

SOARCA model and results

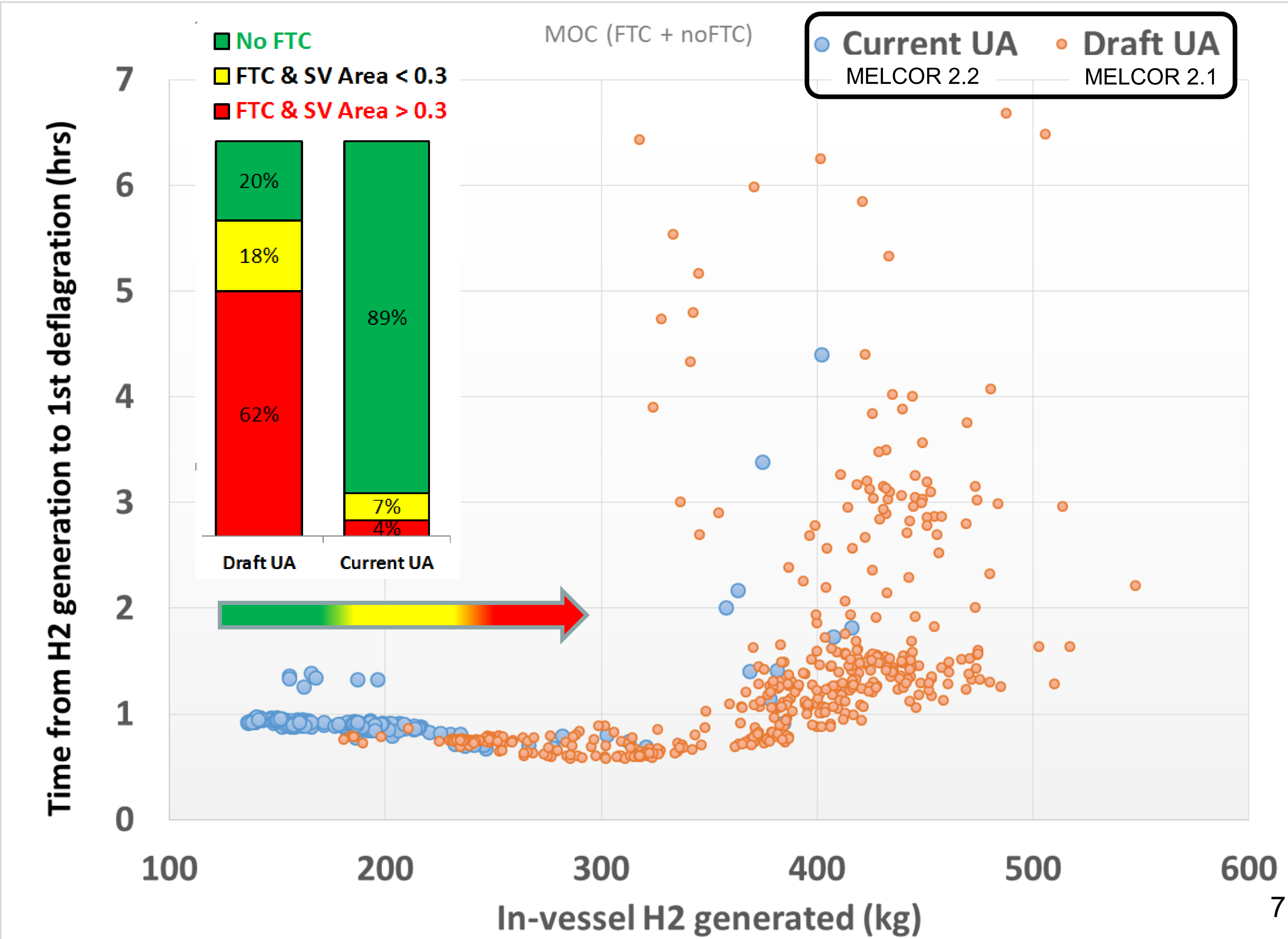
- Used in NRC training classes
- Used for staff knowledge about plant models
- Informs L3 PRA in modeling and analysis of severe accidents and consequences
- Updates the input decks for future needs and timely response in-house
  - MACCS and MELCOR decks can be applied to many scenarios beyond SBO
- Inform international research planning and benchmarking
  - MAAP-MELCOR-ASTEC crosswalk of Fukushima Unit 1 melt progression

SOARCA studies cited in >270 publications domestically and internationally

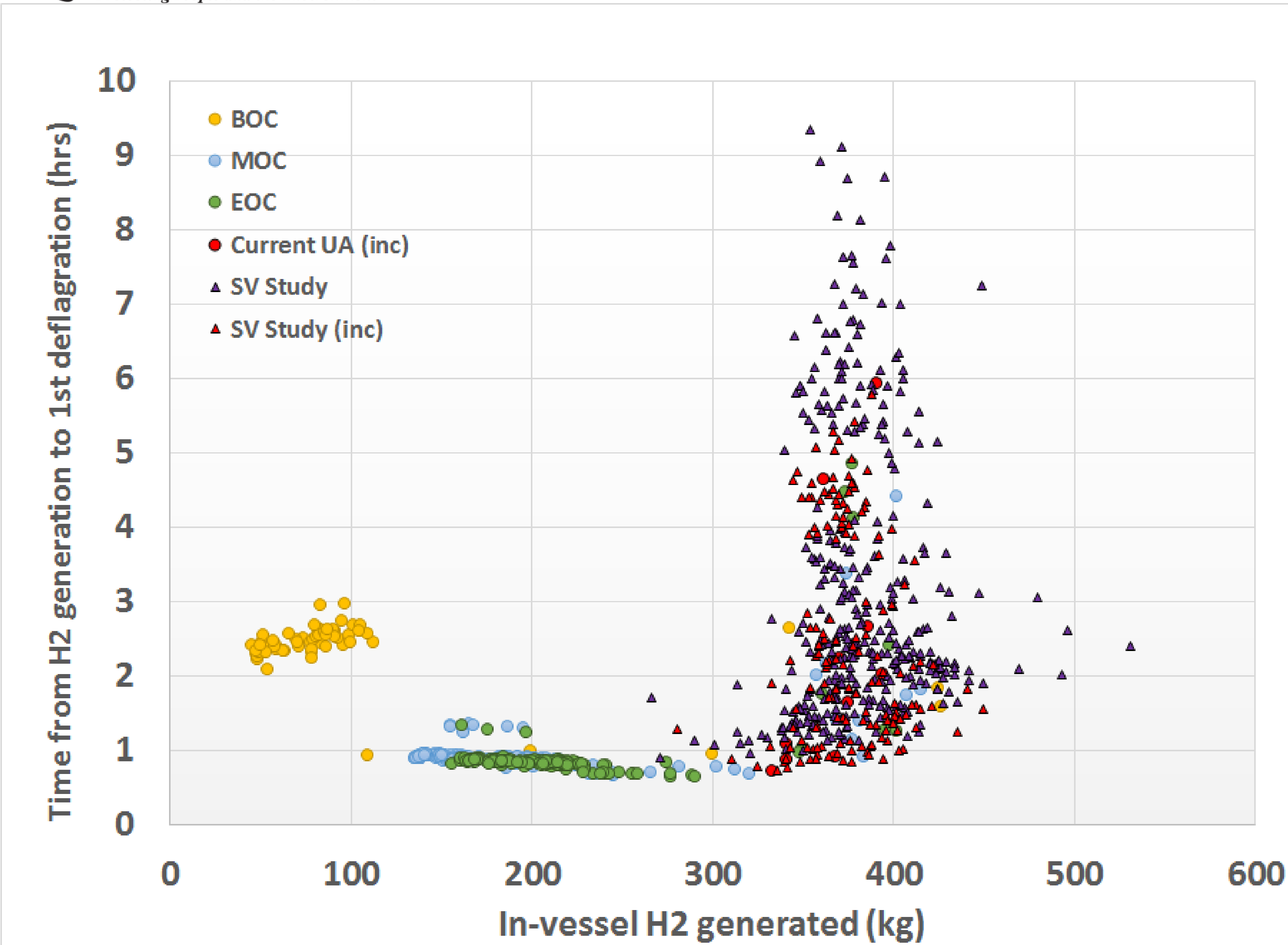
Severe Accident Progression STSBO High Level General Observations

- Consequences strongly (and intuitively) affected by *early vs. late* containment failure. Early containment failure dominated by hydrogen combustion, and late containment failure results mainly from ex-vessel phenomena (e.g., CCI)
- Early containment failures occur *only on the first hydrogen burn* (subsequent burns do not challenge containment integrity)
- Protracted safety valve (SV) cycling produces *lower in-vessel hydrogen* by the time of first burn
- Pressurizer SV failure to close (with large open area) results in greater hydrogen production and transport to the containment prior to the first burn, which increases the potential for early containment failure
- Late containment failures generally have reduced source term release benefiting from gravitational settling

STSBO (Effect of SV)

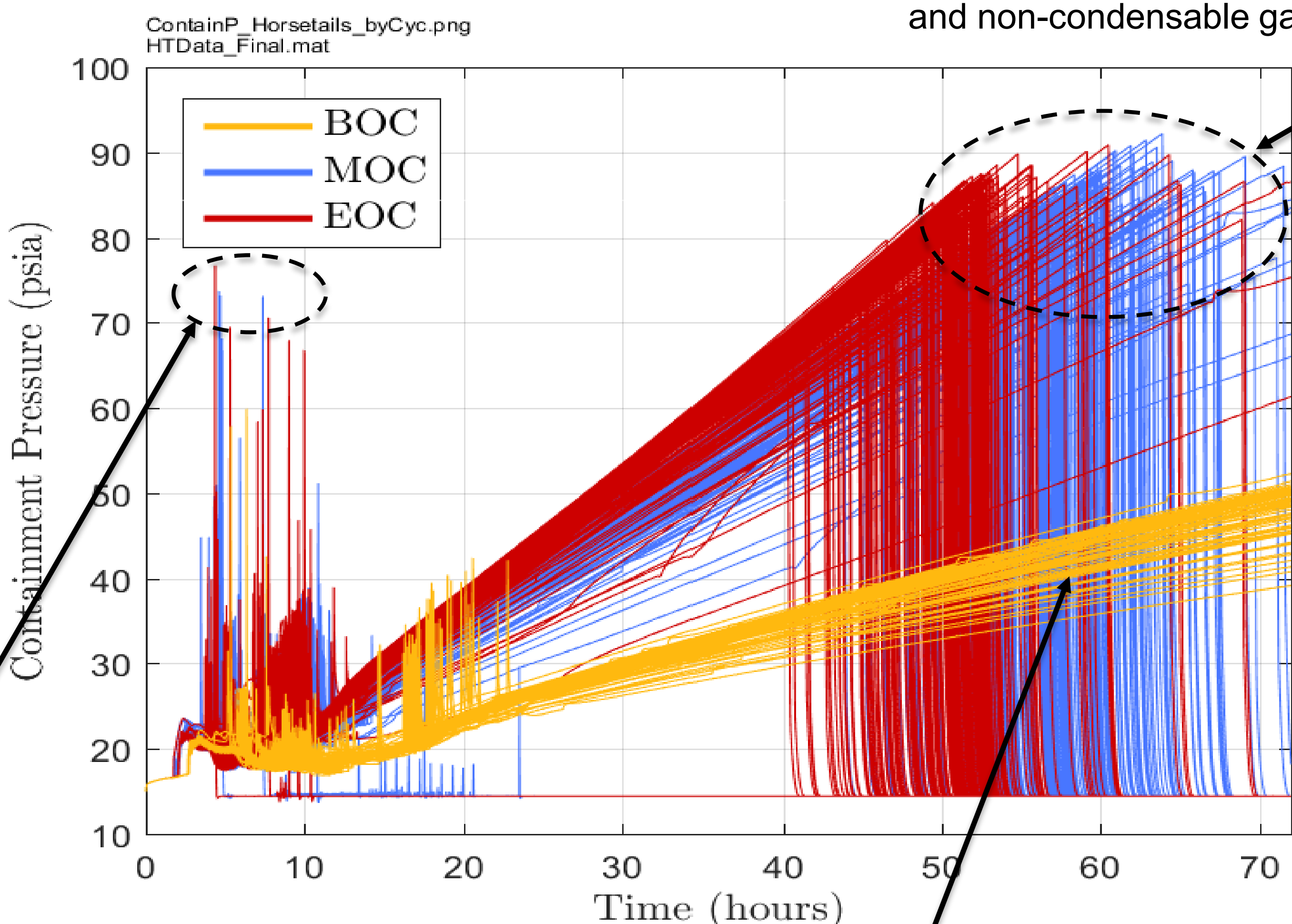


STSBO (Effect of SV)



Containment Failure Outcomes

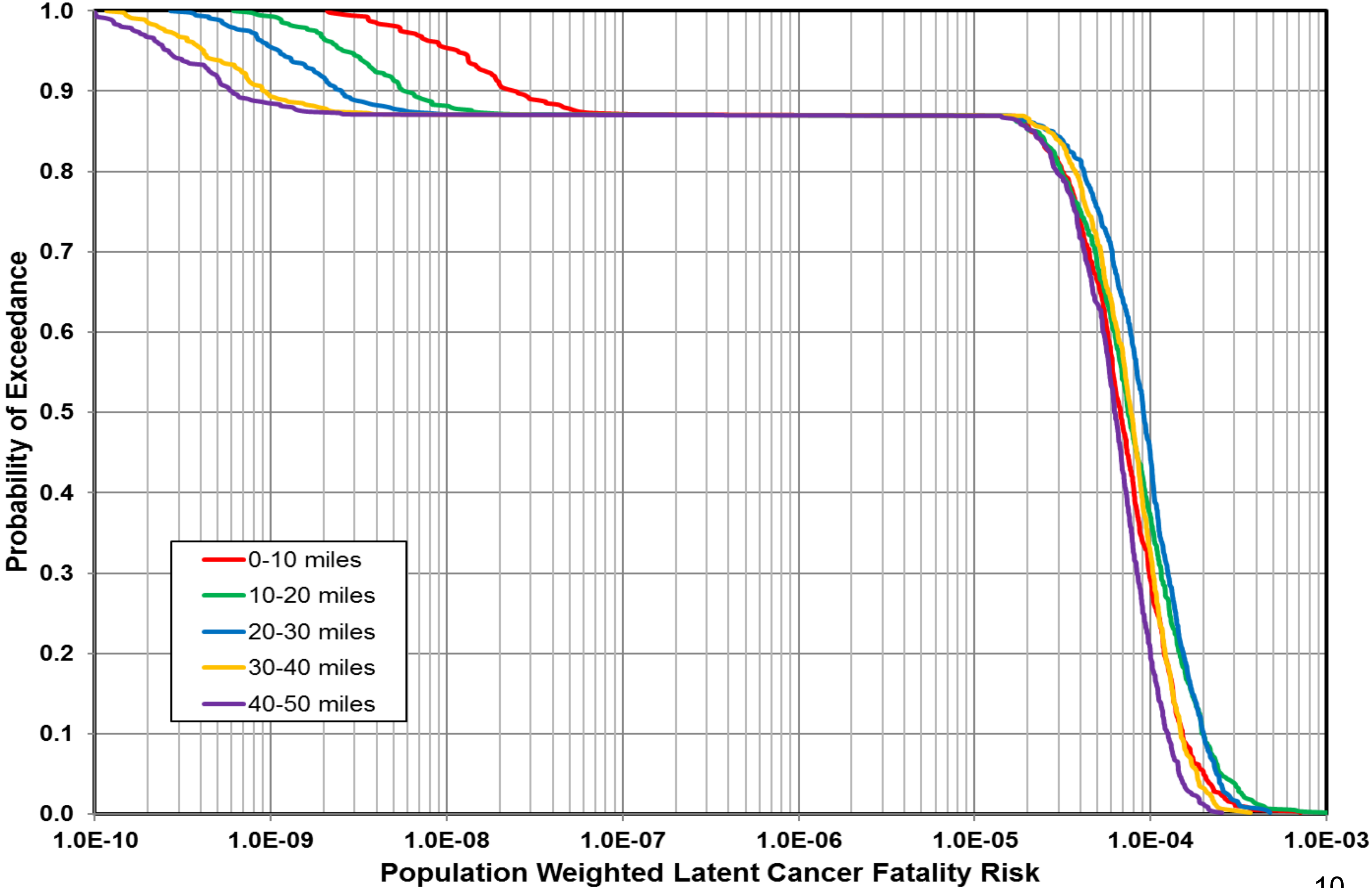
Long-tem containment over-pressurization failure due to prolonged steam production and non-condensable gas generation



Early containment overpressure failures due to sufficiently large burns in containment

No BOC cases exhibit long-term overpressure failure before 72 hours

Latent Cancer Fatality Risk (mean over weather trials), Conditional on the STSBO accident Occurring (per event)



Offsite Consequence Analysis Summary

- Essentially zero individual early fatality risk was calculated for Sequoyah STSBO
- Individual, conditional LCF risks:
  - Small, even for cases resulting in early release to environment
  - Generally dominated by intermediate and long-term phase exposures compared to emergency phase exposures
- Parameters most important to uncertainty in LCF risk:
  - Time during fuel cycle when accident occurs
  - Cancer fatality risk factors for “residual” organ, lungs, and colon
  - Containment rupture pressure
  - Number of safety valve cycles prior to failing open (more important at shorter distances)
  - Normal relocation time (important beyond 10-mile EPZ)

Lessons Learned

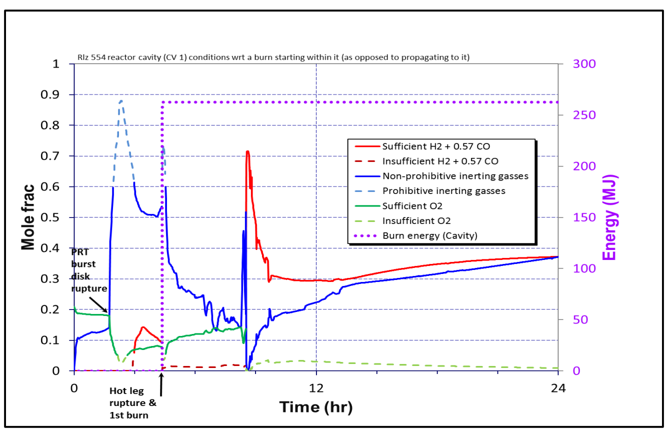
- A single "best-estimate" severe accident simulation is elusive due to many and varied uncertainties
- UA is an iterative process requiring complementary statistical and phenomenological expertise and analyses

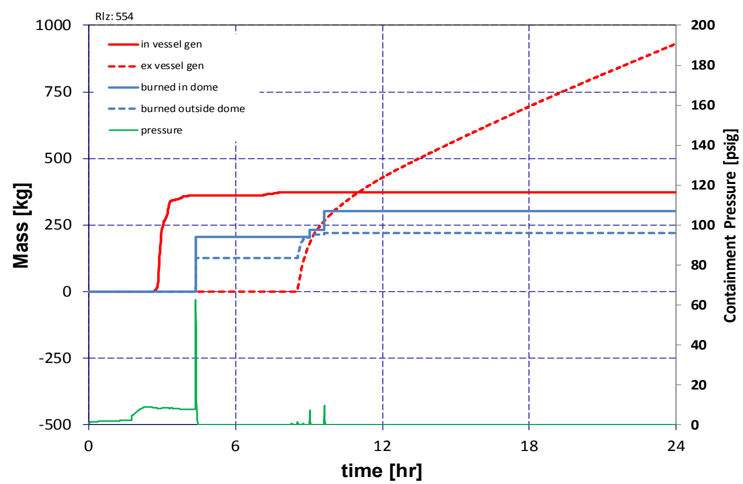
Cesium Regression Table

Sequoyah_Final_RegResults_R2_Cs.png
Data: RegData_Final.xlsx

	Rank Regression		Quadratic		Recursive Partitioning		MARS		Main Contribution	Conjoint Contribution
Final R^2	0.40		0.77		0.51		0.77			
Input	R^2 contr.	SRRC	S_i	T_i	S_i	T_i	S_i	T_i		
priSVcyc	0.26	-0.53	0.32	0.86	0.58	0.96	0.41	0.76	0.280	0.294
Cycle	0.01	0.15	0.04	0.10	0.01	0.02	0.21	0.21	0.051	0.019
Rupture	0.05	-0.22	0.01	0.14	---	---	0.01	0.09	0.016	0.051
Eu_Melt_T	0.02	-0.15	0.02	0.27	0.02	0.40	0.01	0.30	0.013	0.205
Shape_Fact	0.04	0.21	---	---	0.00	0.00	0.00	0.00	0.010	0.000
Ox_Model	0.01	0.09	0.01	0.16	---	---	0.00	0.00	0.004	0.039
Fseal_Pressure	---	---	0.00	0.02	---	---	0.01	0.01	0.002	0.005
Seal_Open_A	0.01	-0.07	0.00	0.01	---	---	0.00	0.00	0.002	0.004
Burn_Dir	0.00	0.07	0.00	0.02	---	---	0.00	0.01	0.001	0.006

** highlighted if main contribution larger than 0.02 or conjoint contribution larger than 0.1*

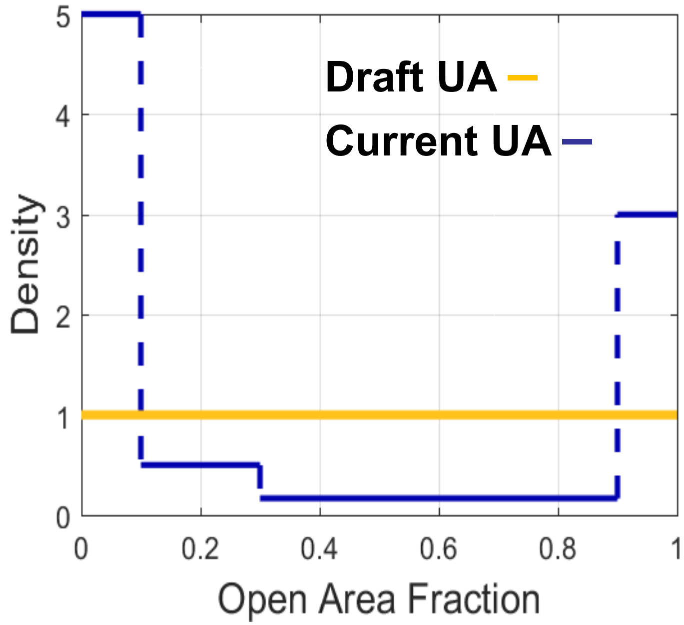


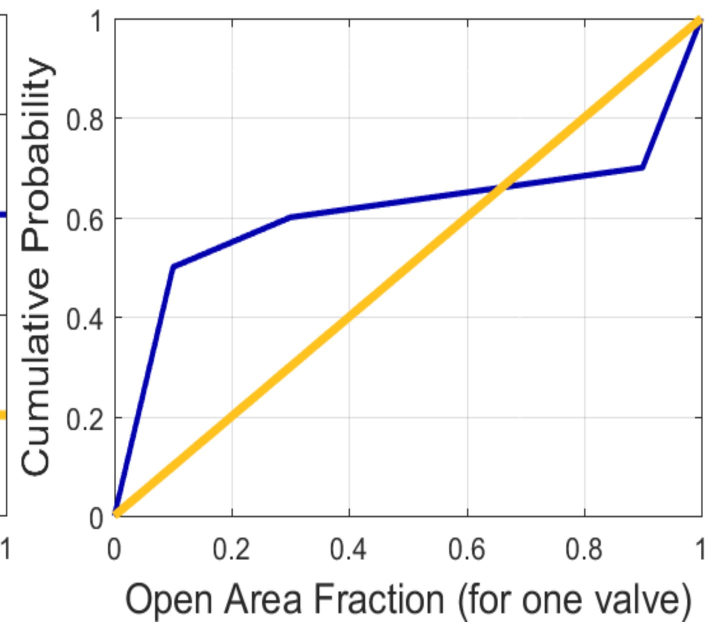


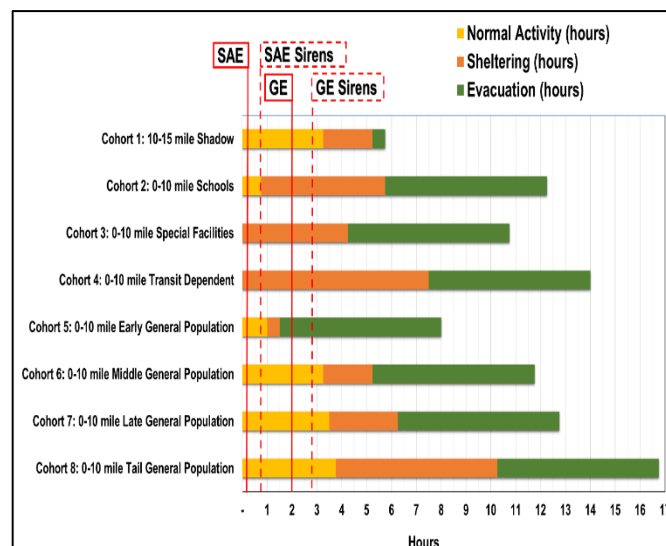
The case with earliest containment rupture – RLZ 554

Lessons Learned (cont.)

- Important to consider uncertainty within the overall analysis
  - SV Open Area Fraction distribution updated
- Integrated modeling important
  - Impact of assumed seismic initiator on evacuation







Core Team Members

- MELCOR and severe accident progression: Kyle Ross, Jeff Cardoni, Chris Faucett, Troy Haskin, Randy Gauntt (SNL); Casey Wagner (dycoda); Hossein Esmaili, Trey Hathaway, Allen Notafrancesco, Salman Haq, Ed Fuller (NRC)
- MELMACCS: Nathan Bixler, Doug Osborn** (SNL); Trey Hathaway (NRC)
- MACCS, consequence analysis and emergency response: Nathan Bixler, Matthew Dennis, Joe Jones, Doug Osborn**, Fotini Walton (SNL); Trey Hathaway, Jonathan Barr, Keith Compton, Todd Smith, Edward Roach (NRC);
- UA methodology: Dusty Brooks, Matthew Denman (SNL); Tina Ghosh**, Trey Hathaway (NRC)
- Accident scenario development: Selim Sancaktar, Jose Pires (NRC)

***Co-leads*

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Summary

- Objectives met for pilot analyses
- Major step forward in realistic, integrated approach
- SOARCA important reference domestically and internationally
- Improved accident codes and models
- Key knowledge development and experience for staff

References

- SECY-12-0092, "State-of-the-Art Reactor Consequence Analyses – Recommendation for Limited Additional Analysis" (July 2012)
- NUREG-1935, State-of-the-Art Reactor Consequence Analyses (SOARCA) Report (November 2012)
- NUREG/CR-7110, Vol. 1, SOARCA Project Peach Bottom Integrated Analysis, Rev. 1, (May 2013)
- NUREG/CR-7110, Vol. 2, SOARCA Project Surry Integrated Analysis, Rev. 1 (August 2013)
- NUREG/CR-7008, MELCOR Best Practices as Applied in the SOARCA Project (August 2014)
- NUREG/CR-7009, MACCS Best Practices as Applied in the SOARCA Project (August 2014)
- NUREG/CR-7155, SOARCA Project Uncertainty Analysis of the Unmitigated Long-Term Station Blackout of the Peach Bottom Atomic Power Station (May 2016)
- NUREG/BR-0359, Modeling Potential Reactor Accident Consequences, Rev. 1 (December 2012, update in progress)

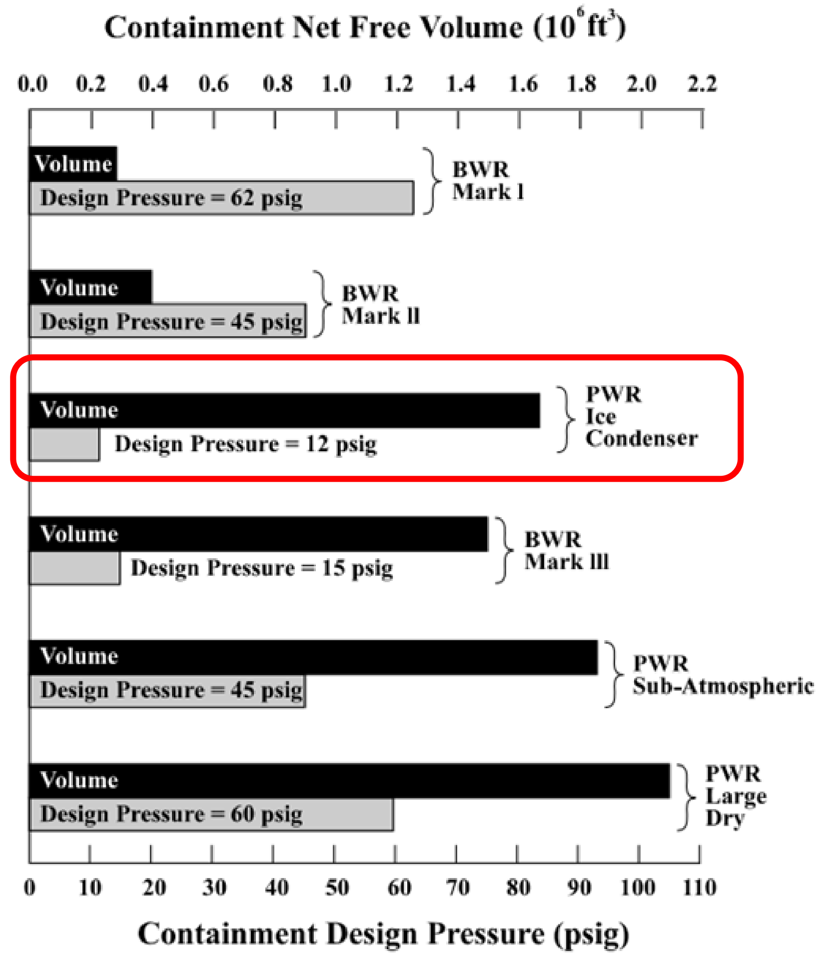
Acronyms & Abbreviations

AC	Alternating Current
BOC	Beginning of Cycle
CCDF	Complementary Cumulative Distribution Function
CCI	Core Concrete Interactions
CDF	Core Damage Frequency
CST	Condensate Storage Tank
DC	Direct Current
EOC	End of Cycle
EPZ	Emergency Planning Zone
EF	Early Fatality
GE	General Emergency
HL	Hot Leg
FLEX	Diverse and Flexible Coping Strategies
FTC	Failure to Close
FTO	Failure to Open
LCF	Latent Cancer Fatality
LNT	Linear No Threshold
LTSBO	Long-Term Station Blackout
MACCS	MELCOR Accident Consequence Code System
MCR	Main Control Room
MELCOR	Not an acronym - accident progression code
MelMACCS	MELCOR to MACCS Source Term Converter
MOC	Middle of Cycle
MSIV	Main Steam Isolation Valve
NTTF	Fukushima Near-Term Task Force
PDF	Probability Density Function
PGA	Peak Ground Acceleration
PRA	Probabilistic Risk Assessment
PRT	Pressurizer Relief Tank
PZR	Pressurizer
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RLZ	Realization
RPV	Reactor Pressure Vessel
RtePM	Real Time Evacuation Planning Model
SBO	Station Blackout
SG	Steam Generator
SAE	Site Area Emergency
SIP	Shelter in Place
SME	Subject Matter Expert
SNL	Sandia National Laboratories
SOARCA	State-of-the-Art Reactor Consequence Analysis
STSBO	Short-Term Station Blackout
SV	Safety Valve
TDAFW	Turbine Driven Auxiliary Feedwater System
TVA	Tennessee Valley Authority
UA	Uncertainty Analysis

Backup Slides

Ice Condenser Containment

- Relatively low design pressure and smaller volume leads to potential susceptibility to early failure from hydrogen combustion in a station blackout
- Analyzed in Generic Safety Issue program (GSI-189)



Code Updates

Draft vs. current UA

- Various MELCOR 2.2 code updates including
  - Corrections to the reflood quench model
  - Lipinski dryout model not used above the core support plate
  - Decay heat transfer to small fluid volumes
  - Correction to fuel rod collapse modeling (temperature failure criteria)
  - Ex-vessel debris cooling and spreading models
- Presentation to ACRS on April 18, 2017
  - Changes in early containment failures in current UA (MELCOR 2.2) calculations are mainly due to modifications in the safety valve failing to close
  - Reduction in hydrogen generated in-vessel due to code changes not as important as model input changes

MELCOR Model Parameters (STSBO)

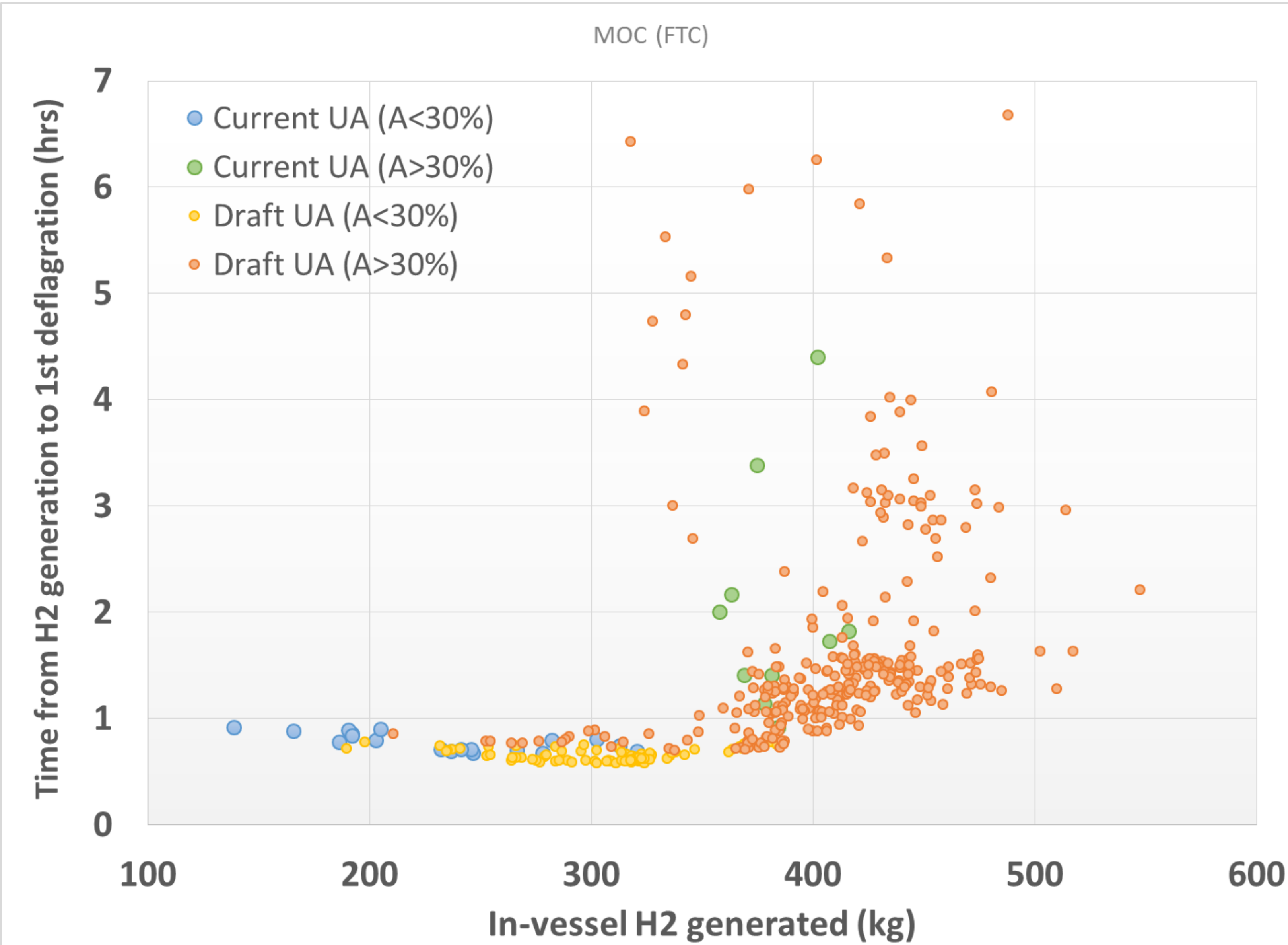
Figures of merit studied include cesium/iodine release magnitude, in-vessel hydrogen generation, containment failure time, and time of initial release

Table ES-1 Uncertain MELCOR parameters used in unmitigated STSBO UA

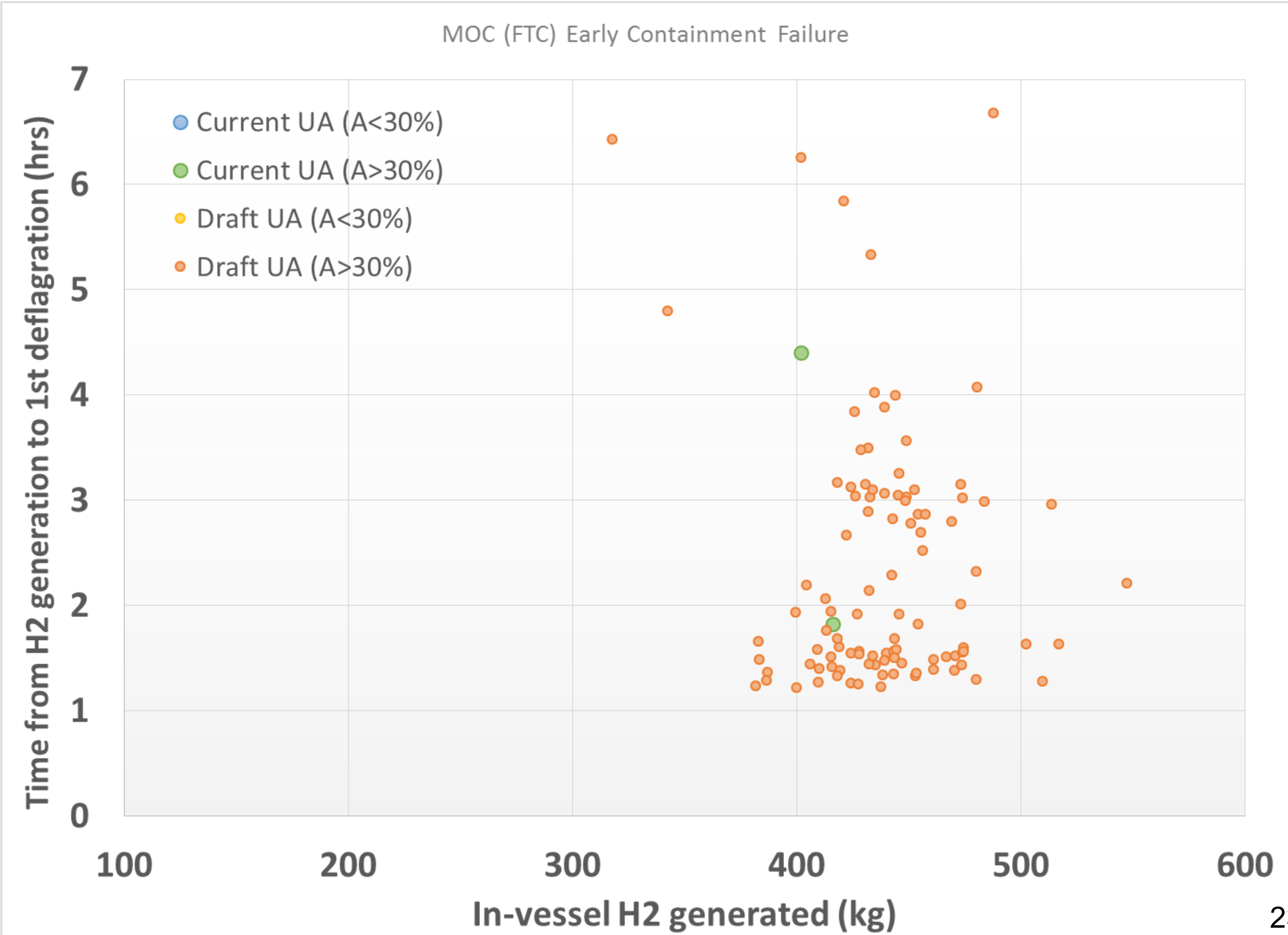
Sequence Related Parameters
Primary safety valve stochastic number of cycles until failure-to-close
Primary safety valve open area fraction
Secondary safety valve stochastic number of cycles until failure-to-close
Secondary safety valve open area fraction
In-Vessel Accident Progression
Melting temperature of the eutectic formed of fuel and zirconium oxides
Oxidation kinetics model
Ex-Vessel Accident Progression
Lower flammability limit hydrogen ignition criterion for an ignition source in lower containment
Containment rupture pressure
Barrier seal open area
Barrier seal failure pressure
Ice chest door open fraction
Particle dynamic shape factor
Time within the Fuel Cycle
Time-in-cycle

Orange indicates additional parameters considered in current UA
Blue indicated updated parameters considered in the current UA

STSBO - Effect of SV area fraction



STSBO – Early Containment Failure Map



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Basic UA Statistics

- In the 600 total UA calculations, 567 completed to 72 hours
- Of the completed calculations
  - 4 failed containment early on a sudden increase in pressure immediate to the first hydrogen deflagration
  - 492 failed containment between 36 and 72 hours after a gradual monotonic progression in pressure to rupture
  - 71 did not fail containment by 72 hours
    - 65 had a BOC reactor core represented
- In the 600 total UA calculations, 85 had a pressurizer SV FTC; of these 85:
  - 40 had a fractionally open position of the failed valve greater than 0.3
    - 17 failed to complete, meaning that only 23 of the total 600 UA calculations actually had potential to fail containment early
- First burns were ignited by hot gas issuing from the PRT in 23 of the successful 567 UA calculations and among these 23 there were 2 early containment failures

General Observations and Findings From STSBO Accident Progression

Early Containment Failures (4 out of 567)

- Consequences strongly (and intuitively) affected by *early vs. late* containment failure
- Early containment failures occur *only on the first hydrogen burn* from in-vessel generated hydrogen
- In-vessel generated hydrogen is maximized when pressurizer SV sticks open early at greater than 30% open and with higher temperature fuel collapse criteria
- First burns that fail containment initiated in lower compartment from HL rupture or PRT venting and propagate to dome where more than 150kg hydrogen was present
- Some early burns were just under the sampled containment failure pressure
- Early containment failure source terms generally higher due to unsettled airborne fission products

Late Containment Failures (492 out of 567)

- Protracted SV cycling produces *lower in-vessel hydrogen*
- Ex-vessel CCI-generated hydrogen greatly exceeds in-vessel hydrogen but produces ongoing small burns
- Ex-vessel burns in cavity prevent large dome hydrogen concentrations from accumulating
- Late hydrogen burns are terminated by insufficient oxygen for combustion
- Late containment failures from static overpressure: increasing temperature, rising steam pressure, accumulating gases
- BOC and some MOC did not fail containment before 72 hours due to lower decay heat and slower pressurization
- Late failures generally have reduced source term release benefiting from gravitational settling

Sequoyah STSBO: MACCS Uncertain Parameter Groups

Deposition
- Wet Deposition
- Dry Deposition Velocities

Dispersion
- Crosswind Dispersion Linear Coefficient
- Vertical Dispersion Linear Coefficient
- Time-Based Crosswind Dispersion Coefficient

Latent Health Effects
- Dose and Dose Rate Effectiveness Factor
- Lifetime Cancer Fatality Risk Factors
- Long Term Inhalation Dose Coefficients

Early Health Effects
- Threshold Dose
- Lethal Dose to 50% of population
- Hazard Function Shape Factor

Shielding Factors
- ***Groundshine Shielding Factors****
- ***Inhalation Protection Factors****

Emergency Response
- ***Evacuation Delay****
- ***Evacuation Speed****
- Hotspot Relocation Time and Dose Criteria
- Normal Relocation Time and Dose Criteria
- Keyhole Forecast Time

Aleatory Uncertainty
- Weather Trials

*Blue text indicates parameters updated from earlier draft Sequoyah SOARCA report (ML16096A374)

Mean, Individual, LCF Risk Regression Results within 0 – 10 mile and 0 – 50 mile for STSBO Based on LNT

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0 – 10 Mile

	Rank Regression		Quadratic		Recursive Partitioning		MARS		Main Contribution	Conjoint Contribution
Final R^2	0.67		0.86		0.58		0.78			
Input	R^2 contr.	SRRC	S_i	T_i	S_i	T_i	S_i	T_i		
Cycle	0.36	0.58	0.23	0.29	0.40	0.60	0.20	0.20	0.237	0.056
priSVcyc	---	---	0.04	0.15	0.12	0.15	0.14	0.31	0.070	0.083
CFRISK(8)	0.09	0.29	0.07	0.12	0.08	0.23	0.10	0.09	0.068	0.042
Rupture	0.06	-0.24	0.06	0.08	0.07	0.18	0.09	0.15	0.054	0.046
CFRISK(7)	0.03	0.19	0.06	0.10	0.05	0.11	0.08	0.10	0.040	0.031
GSHFAC_6(2)	0.05	0.22	0.02	0.06	0.01	0.05	0.04	0.03	0.026	0.021
CFRISK(6)	0.01	0.09	0.04	0.11	---	---	0.04	0.07	0.018	0.029
CFRISK(3)	0.02	0.11	---	---	0.00	0.01	0.03	0.10	0.011	0.018
DDREFA(8)	0.01	-0.11	0.03	0.04	---	---	---	---	0.010	0.002

** highlighted if main contribution larger than 0.02 or conjoint contribution larger than 0.1*

0 – 50 Mile

	Rank Regression		Quadratic		Recursive Partitioning		MARS		Main Contribution	Conjoint Contribution
Final R^2	0.59		0.86		0.65		0.75			
Input	R^2 contr.	SRRC	S_i	T_i	S_i	T_i	S_i	T_i		
Cycle	0.23	0.52	0.24	0.31	0.36	0.44	0.21	0.21	0.208	0.038
CFRISK(8)	0.06	0.24	0.09	0.13	0.05	0.14	0.09	0.08	0.059	0.029
Rupture	0.05	-0.21	0.06	0.10	0.05	0.22	0.10	0.25	0.052	0.086
CFRISK(4)	0.05	0.23	0.07	0.10	0.04	0.15	0.08	0.09	0.048	0.037
CFRISK(7)	0.04	0.22	0.05	0.07	0.02	0.10	0.08	0.11	0.040	0.028
TIMNRM	0.04	0.22	0.04	0.07	0.06	0.30	0.05	0.06	0.038	0.061
CYSIGA(1)	0.03	0.19	0.03	0.04	0.01	0.05	---	---	0.015	0.013
DDREFA(4)	0.02	-0.13	0.02	0.02	0.00	0.04	0.02	0.02	0.013	0.011
CFRISK(6)	0.01	0.08	0.03	0.12	---	---	0.02	0.08	0.012	0.042

** highlighted if main contribution larger than 0.02 or conjoint contribution larger than 0.1*

Mean (over weather variation) individual early fatality risk , conditional on accident occurring (per event)

	0 - 1 miles	0 - 1.3 miles	0 - 2 miles
Mean	3.0E-09	1.8E-09	8.6E-10
Median	0.0E+00	0.0E+00	0.0E+00
5th percentile	0.0E+00	0.0E+00	0.0E+00
95th percentile	0.0E+00	0.0E+00	0.0E+00

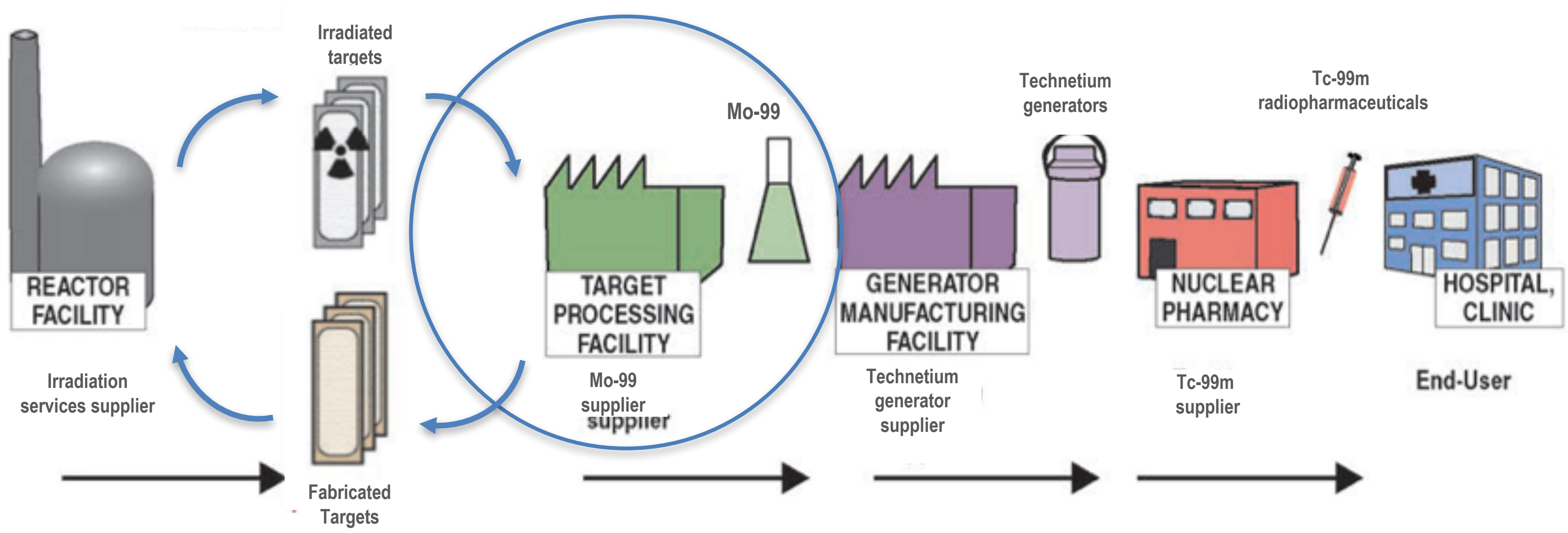
- Nonzero early fatality risk within 1 mile for three realizations
- No early fatality risk beyond 2 miles for any realization
- Only 3 realizations out of 567 resulted in non-zero early fatalities

U.S. Nuclear Regulatory Commission
Advisory Committee on Reactor Safeguards

Public Session

November 2, 2017

Business Model



- Captive Network of University Research Reactors
  - Reliability/assurance of supply
  - Multiple shipments/week
- Radioisotope Production Facility (RPF)
  - Fabrication of LEU targets
  - Mo-99 production
  - Uranium recycle and recovery
- Domestic Mo-99 Generator Distributors
  - Hold FDA Drug Master File
  - No changes to generators
  - No changes to supply chain

OSU Oregon State University MISSOURI

Lantheus Medical Imaging CURIUM LIFE FORWARD GE Healthcare

University Reactor Network and NWMI Location

FUTURE HOME OF
NWMI
NORTHWEST MEDICAL ISOTOPES
WELCOME TO COLUMBIA/
BOONE COUNTY
University of Missouri System
redi Regional Economic Development Inc.

- 6 mi to MURR
- 5 mi to regional airport
- 3rd Reactor selection complete but not yet socialized
- 100 mi to Mallinckrodt
- Anchor of isotope "ecosystem"

Siting – Discovery Ridge Research Park

- University system owned 550 acre research park
- NWMI “anchor” for radioisotope ecosystem; two existing companies (RADIL and ABC Laboratories)
- RPF would be located in Lot 15 of the Discover Ridge Phase II section (54.9 acres)
- Lot 15 is 7.4 acres and contains no existing structures
- Research Park being developed under guidance of the Master Plan Protective Covenants (MU, 2009)

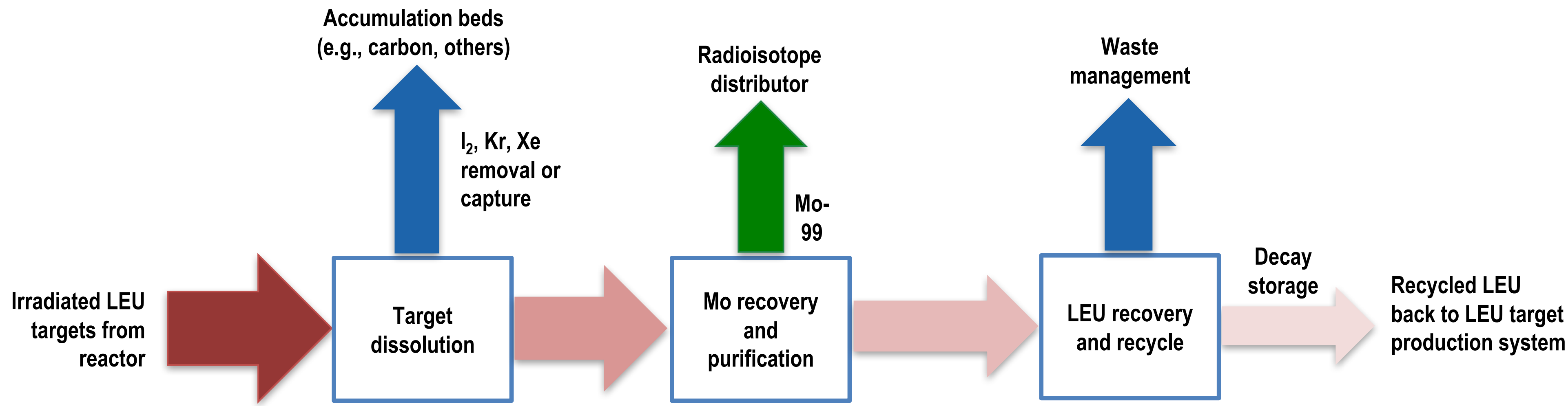
Source: MU, 2011, “Phasing Overview,” Maps and Roads, Research Parks & Incubators, Discovery Ridge, www.umsystem.edu/umrpi/discoveryridge/maps, University of Missouri, Columbia, Missouri, accessed July 2013.

RPF Facility Layout – Lot 15

NWMI
NORTHWEST MEDICAL ISOTOPES

Primary Assumptions

- Single radioisotope production facility (RPF)
  - RPF includes target fabrication, Mo-99 production, and uranium recycle & recovery
    - Simple/straightforward chemistry processes
  - Mo-99 produced using a fission-based method – "Gold Standard" using LEU
  - Nominal capacity 3,500 6-day Ci; surge capacity of 1,500 6-day Ci
- Use network of university reactors
  - Use same target design for all reactors
  - Intellectual Property obtained
    - U.S., Australia, Russia, South Africa, Korea → Allowed
    - India, Europe, China → Pending



NRC Licensing Strategy

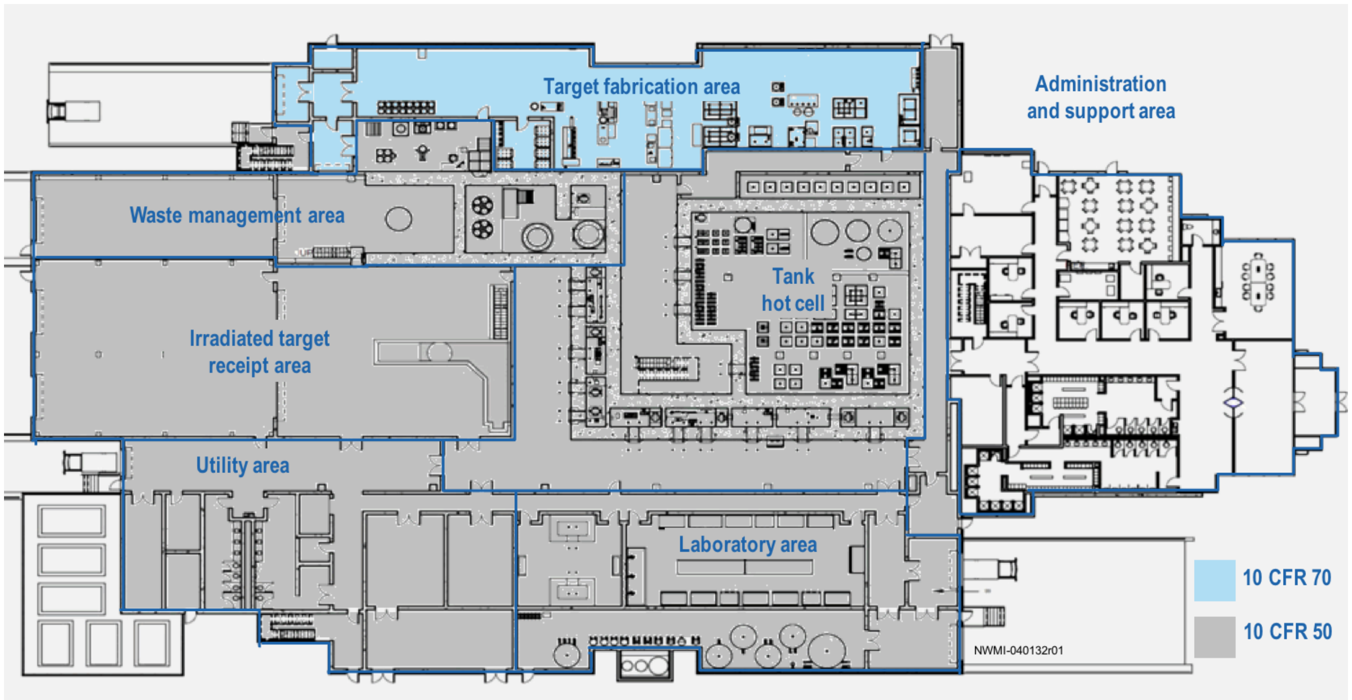
- Combine several license activities and submit one application that covers all applicable regulations for construction/operation of the RPF under 10 CFR 50

10 CFR 50 Activities
- Irradiated target receipt
- Irradiated target disassembly
- Target dissolution
- ^{99}Mo separations, purification, and packaging
- Uranium (U) recycle and recovery
- Waste management
- Associated laboratory and support

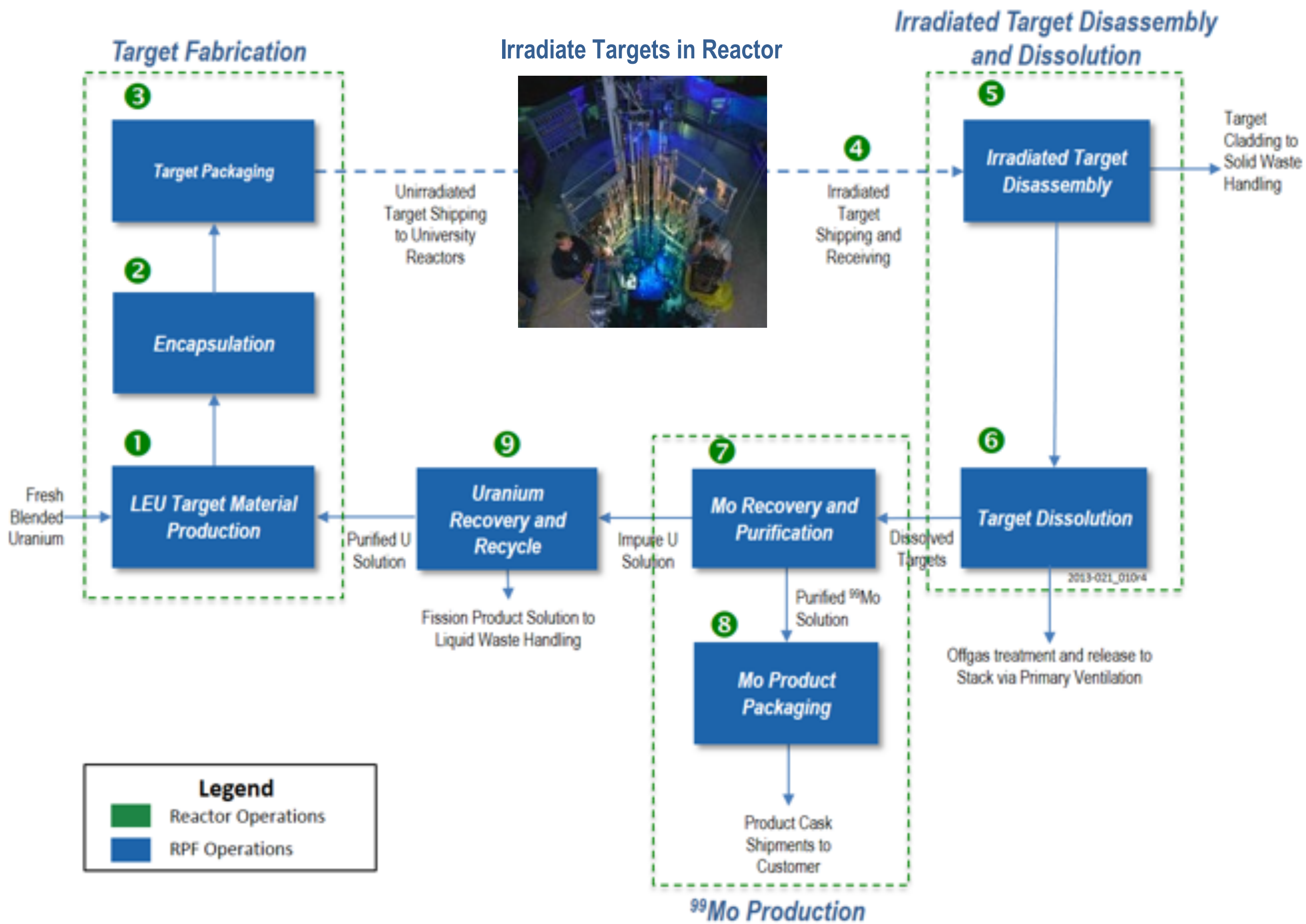
10 CFR 70 Activities
- Receipt of low-enriched uranium (LEU) (from DOE)
- Production of LEU microspheres
- Target fabrication and testing
- Shipping/loading of fabricated targets
- Laboratory and support areas

10 CFR 30 Activities
- Handling of byproduct material

- University reactor(s) and cask licensee(s) will amend their current operating licenses



RPF Process Flow Diagram



- ❶ LEU target material is fabricated (both fresh LEU and recycled U)
- ❷ LEU target material encapsulated using metal cladding → LEU target
- ❸ LEU targets are packaged and shipped to university reactors for irradiation
- ❹ After irradiation, targets are shipped back to RPF
- ❺ Irradiated LEU targets disassembled
- ❻ Irradiated LEU targets dissolved into a solution for processing
- ❼ Dissolved LEU solution is processed to recover and purify ^{99}Mo
- ❽ Purified ^{99}Mo is packaged/shipped to a radiopharmaceutical distributor
- ❾ LEU solution is treated to recover U and is recycled back to Step 1

Facility Description

- First level footprint ~52,000 ft^2
  - Target fabrication area
  - Hot cell processing area (dissolution, ^{99}Mo, and ^{235}U recovery)
  - Waste management, laboratory and utility areas
- Basement ~2,000 ft^2 (tank hot cell, decay vault)
- Second level ~17,000 ft^2 (utility, ventilation, offgas equipment)
- Waste Management Building ~1,200 ft^2
- Administration Building (outside of secured RPF area) ~10,000 ft^2

- High bay roof – 65 ft
- Mechanical area, second floor – 46 ft
- Top of exhaust stack – 75 ft
- Loading dock (back) roof – 20 ft
- Support and admin (front) roof – 12 ft
- Depth below grade for hot cell/high-integrity container (HIC) storage – 15 ft

Project Schedule (Calendar Year)

- Start date of site preparation/construction → Q2 2018
- End date of construction → Q2 2019
- Start date of facility startup and cold commissioning (pre-operational) → Q3 2019
- Date of hot commissioning and commercial operations → Q4 2019/Q1 2020
- Date of decommissioning: 2050

NWMI
NORTHWEST MEDICAL ISOTOPES

Chapter 2 – Miscellaneous

- Transient population
- Nearby industrial, transportation, and military facilities
  - Airports/Heliports
  - Pipelines
  - Highways
  - Nearby facilities
- Geotechnical investigation
- Maximum probable precipitation in a one-hour period is 3.14 in/hour
- Seasonal and annual frequency of historical tornadoes (1954 – 2016) updated
- Seasonal and annual thunderstorm wind events (1955 – 2016) updated
- Lighting events (1998 – 2016) updated
- Seasonal and annual hail events (1958 – 2016) updated
- Winter weather events (1996 – 2016) updated
- Recorded Missouri earthquake history updated

Chapter 3 – RPF Design Evolution

- RPF design is being completed in stages
- RPF preliminary design complete and final design initiated
- Final design is needed to develop Operating License (OL) Application and construction drawings
- Construction documentation consists of drawings and specifications
  - Describe quality, configuration, size, and relationship of all components of RPF
  - Serve as a basis for obtaining bids from contractors
- All supporting documentation will be finalized, which includes but is not limited to:
  - Final hazards analysis and associated qualitative risk assessment
  - Integrated safety analysis
  - Criticality safety evaluations and associated calculations
  - Criticality safety program
  - Criticality accident alarm system/dose analyses
  - Shielding analysis
  - Fire hazards analysis
  - Radiation protection program
  - Waste management program
  - Material control and accountability program
  - Natural phenomena hazards/external events analysis
  - Emergency preparedness program
  - Quality assurance program
  - Safeguards and security program

Chapter 2 and 3 – Seismic

- Probabilistic seismic hazard analysis (PSHA) was performed by NRC staff for University of Missouri Research Reactor (MURR) site to assess seismic safety of reactor facility using present-day methodologies
- Seismic hazard curves were estimated at control point (top of weathered rock layer)
  - 10^{-4} and 10^{-5} uniform hazard response spectra were also calculated using results of confirmatory PSHA and site response analyses and ground motion response spectra (GMRS) was computed using Regulatory Guide 1.208
- NWMI compared seismic GMRS with peak ground acceleration of 0.2 g
  - Used in Callaway Nuclear Plant and MURR
- GMRS is enveloped by seismic response spectrum with peak ground acceleration of 0.2 g up to about 16 hertz (Hz)
- Based on EPRI guidance, ground motions at higher than approximately 10 Hz frequency are not damaging to SSCs of a nuclear reactor, except functional performance of components sensitive to vibration (e.g., electrical relays)
- If electrical relays are fail-safe on excess vibration or loss of power, safety function of such relays will not be compromised
- NWMI will evaluate dynamic analyses of RPF structural components
- NWMI will define specific acceptable qualification methods in procurement packages to demonstrate seismic qualifications

Chapter 3 – Tornado-Generated Missile Impact Effects

- Missile is assumed rigid for maximum penetration
- Expected speed of tornado missiles is larger than expected speed of any hurricane-generated missiles at same annual frequency of exceedance
  - NUREG/CR–7005, *Technical Basis for Regulatory Guidance on Design-Basis Hurricane Wind Speeds for Nuclear Power Plants*
- Tornado-generated missile impact effects are based on standard design missile spectrum from NRC Regulatory Guide 1.76
  - Wind velocities in excess of 75 mi/hr are capable of generating missiles from objects lying within path of tornado wind and from debris of nearby damaged structures
- DOE-STD-1020 (Table 3-4) recommends RPF roof and wall system design criteria

Design-Basis Tornado Missile Spectrum

Description	Weight	Dimensions	Horizontal velocity	Vertical velocity
Automobile	4,000 lb	16.4 ft × 6.6 ft × 4.3 ft	92 mi/hr	62 mi/hr
Pipe	287 lb	6.625 in. diameter × 15 ft long	92 mi/hr	62 mi/hr
Steel Sphere	0.147 lb	1.0 in. diameter	18 mi/hr	12 mi/hr

Source: NRC Regulatory Guide 1.76, *Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, Washington, D.C., March 2007.

Chapter 5 – Coolant Systems

- Weekly Irradiated Target Heat Generation rate added
- Thermal load is characterized by radial heat transfer in a vessel and uranium concentration of solutions held within vessels throughout RFP
- Number of targets to be irradiated will be optimized in Operating License (OL) Application

Chapter 6 – Criticality Accident Alarm System

- RPF criticality accident alarm system (CAAS) will meet Title 10 CFR 70.24, *Criticality Accident Requirements*
- NWMI commits to current endorsed version of ANSI/ANS-8.3, *Critically Accident Alarm System*, with modifications as noted in Regulatory Guide 3.71, *Nuclear Criticality Safety Standards for Fuels and Materials Facilities*
- CAAS evaluation will be completed during RPF final design and provided in OL Application
- CAAS coverage will be in all areas in which greater than 10 CFR 70.24 mass limits of SNM are handled, used, or stored, and in all shielding areas of RPF
  - Controls will be established to preclude such SNM from areas where coverage is not provided
  - Each monitored area will be covered by two criticality detectors
- NWMI will establish a CAAS appropriate to RPF for type of radiation detected or shielding and magnitude of minimum accident of concern
  - Will consider potential damages from anticipated adverse events (e.g., fire, explosion)
  - Will be resistant to RPF design-basis earthquake
- Operations will be rendered safe, by shutdown and quarantine, if necessary, in any area where CAAS coverage has been lost and not restored within a specified number of hours
- Emergency power will be provided to CAAS by uninterruptable power supply system

Chapter 6 – Criticality Safety

- Prior to end of construction and with submittal of OL Application, NWMI will ensure that all processes containing SNM within RPF are evaluated to be subcritical under all normal and credible abnormal conditions
- NWMI will use nuclear criticality safety (NCS) controls for mass, geometry, moderation, volume, and interaction
  - NWMI commits to specific criteria for each on parameters under NCS control at RPF
- NWMI commits to evaluate controlled parameters at associated safety limits and to evaluate parameters that are not controlled at most reactive credible values
- NWMI acknowledges that use of a single NCS control to maintain values of two or more controlled parameters constitutes only one component necessary to meet double-contingency principle
- Order of preference for NCS controls will be
  - Passive engineered
  - Active engineered
  - Enhanced administrative
  - Simple administrative controls
- NWMI will make every effort to use passive engineered controls, in particular, passive engineered geometry control
- If RPF operations rely on two or more controls on a single parameter, NWMI commits to using diverse over-redundant means of control

Chapter 6 – Update of USL and Criticality Safety Evaluations

- NWMI will ensure that all processes containing SNM under normal and credible abnormal conditions will meet revised USL of 0.9240
- Criticality safety evaluations (CSE) will be updated during RPF final design
- NCS operating limits will be established based on analyses assuming optimum or most reactive credible values of parameters unless specified controls are implemented to limit parameters to a range of values
  - e.g., most reactive conditions physically possible or bounding values limited by regulatory requirements
- Specific controls and management measures necessary to enforce NCS safety limits and/or operating limits will be specified in each CSE

Chapter 7 – Instrumentation and Control Systems

- FPC system will be a DCS that functions independently
- IROFS/ESF safety functions will be activated via hardwire (analog) interlocks
- Process control system includes interlocks (both hardwired [ESF] and computer logic) to implement an automatic action on a parameter approaching or being outside its setting
  - Interlocks defined as specific set of conditions or parameters that need to be met for an activity to occur
  - Example of an interlock is shutting down a pump on a tank high-level alarm signal or switching to a spare unit or process train based on a change in parameters (and corresponding alarm)
- RPF will also implement a permissive philosophy that allows HMI operations to be enabled once control room has confirmed prerequisites conditions have been completed
  - Permissives differ from interlocks in that permissives require manual approval via a switch (or similar) that must be satisfied for an activity to occur
  - Interlocks are engineered features, and permissives are administrative features
- Permissive and interlocks will be described in more detail in OL Application

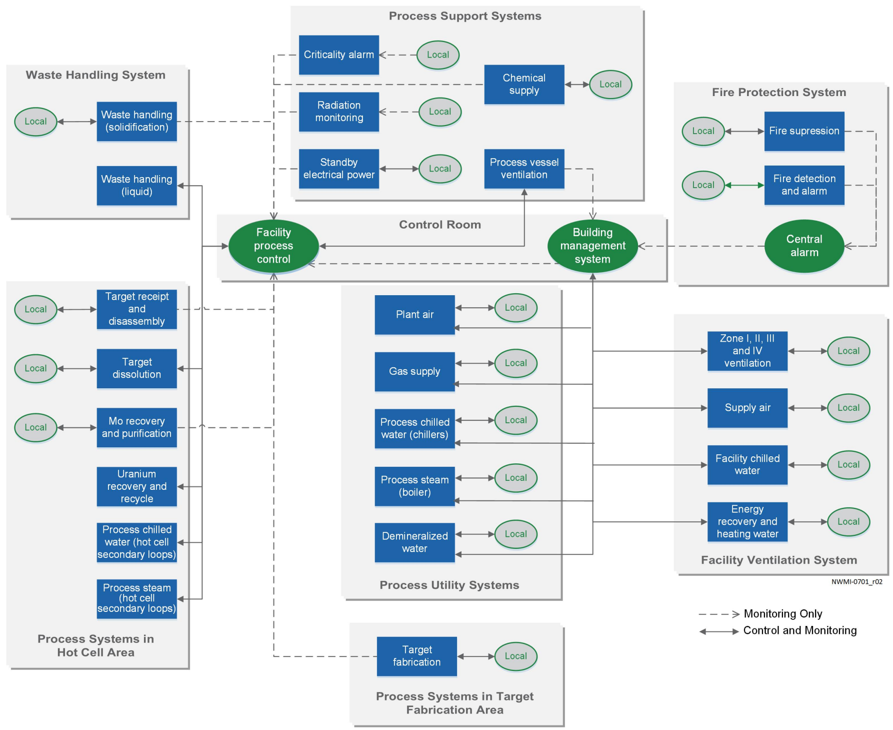


Figure 7-1 Facility Instrumentation and Control System Configuration

Chapter 13 – Uranium Metal Fires

- Targets are fabricated from uranium (U) metal receipts (Y-12) during initial operation
- Evaluated packing and shipping of U metal in compliance with ES-3100 container requirements and planned handling at RPF
  - NWMI-2015-SAFETY-007, *Quantitative Risk Analysis of Facility Fires and Explosions Leading to Uncontrolled Release of Fissile Material, High- and Low-Dose Radionuclides*
- As part of OL application, nonstandard payloads and configurations and failures of hardware/ control will be evaluated including worker safety/exposure from potential U metal fires
  - Controls will be elevated to IROFS for U exposure → 10 CFR 70.61, *Performance Requirements*
- Evaluation in NWMI-2015-SAFETY-007 is based on an existing analysis in SNF-6192-FP, *Uranium Pyrophorocity Phenomena and Prediction*, of ignition test observations for U hydride powder with a characteristic particle diameter of 1.85 micron (μ)
  - Current evaluation indicates that significant particle bed depths (greater than 7 mm) are required to observe ignition at ambient temperature
  - Bed depth to accumulate on a metal shape piece during shipping/storage is considered highly unlikely
- U metal handling activities will be reevaluated and provided in OL Application
- NWMI plans to implement appropriate controls in hood/glovebox to extinguish a U metal fire (e.g. magnesium oxide sand) per DOE-HDBK-1081-2014, *Primer on Spontaneous Heating and Pyrophoricity*

Questions?

Advisory Committee on Reactor Safeguards
Meeting on Northwest Medical Isotopes Construction Permit Application

Northwest Medical Isotopes Production Facility Construction Permit Application Review

Office of Nuclear Reactor Regulation
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
November 2, 2017

Introductions

- **Michael Balazik** - Project Manger, Research and Test Reactors Licensing Branch, Division of Licensing Projects, Office of Nuclear Reactor Regulation
- **David Tiktinsky** - Senior Project Manager, Fuel Manufacturing Branch, Division of Fuel Cycle Safety, Safeguards, and Environmental Review, Office of Nuclear Material Safety and Safeguards
- **Alexander Adams, Jr.** - Chief, Research and Test Reactors Licensing Branch, Division of Licensing Projects, Office of Nuclear Reactor Regulation

Overview of the NWMI Application

- NWMI has submitted a 10 CFR Part 50 construction permit application for a *production facility* to:
  - Disassemble and dissolve low-enriched uranium (LEU) targets
  - Recover and purify molybdenum-99 (^{99}Mo)
  - Recover and recycle uranium
- Two-part construction permit application
  - Environmental Report docketed May 2015
  - Preliminary Safety Analysis Report (PSAR) docketed Dec 2015
- According to NWMI, a 10 CFR Part 70 application for possession and use of special nuclear material (SNM) will be submitted in the future
- Proposes to construct facility in Columbia, MO

NRC Licensing Approach

- NWMI facility includes several hot cell structures, which meet the 10 CFR 50.2 definition of *production facility*

- 10 CFR 50.2 defines *production facility*, in part, as:
  - Any facility designed or used for the processing of irradiated materials containing special nuclear material…
  - If material processed in batches greater than 100 grams of uranium-235

- While NRC has historically licensed Part 50 production facilities, no such facilities are currently operating
  - SHINE was issued a construction permit (for *utilization* and *production* facilities)

NWMI Activities Noted in Application, but Not Part of Construction Permit Safety Review

- Radioisotope production facility (RPF) building would also have a production facility and a target fabrication area
- Target fabrication
  - Processing of unirradiated uranium does not meet the definition of either a *utilization* or a *production facility* (10 CFR Part 50)
  - Processes, activities, and hazards similar to fuel-cycle facility
  - Receipt and possession of fresh LEU (greater than a critical mass), use of SNM, and scrap recovery of SNM
- PSAR Chapter 1 (Rev. 3) states that target fabrication will be applied for under a separate 10 CFR Part 70 license application

NWMI Activities Noted in Application, but Not Part of Construction Permit Safety Review

- Target fabrication SSCs not considered unless shared with the production facility, but no safety findings made on their adequacy for target fabrication

- Target irradiation at research reactors separate application submitted by reactor licensee

- SER findings limited to the 10 CFR Part 50 production facility

Regulatory Guidance and Acceptance Criteria

- NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors"

- Interim Staff Guidance Augmenting NUREG-1537
  - Production facilities
  - Incorporates relevant non-reactor guidance from NUREG-1520, Rev. 1, "Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility"

- Other guidance (e.g., regulatory guides and ANSI/ANS standards) and engineering judgment used, as appropriate, to make construction permit findings

NUREG-1537 and ISG Review Areas

1. The Facility/Introduction
2. Site Characteristics
3. Design of Structures, Systems, and Components
4. Facility Description
5. Coolant Systems
6. Engineered Safety Features
7. Instrumentation and Control
8. Electrical Power Systems
9. Auxiliary Systems
10. Experimental Facilities*
11. Radiation Protection and Waste Management
12. Conduct of Operations
13. Accident Analysis
14. Technical Specifications
15. Financial Qualifications
16. Other License Considerations*
17. Decommissioning*
18. Uranium Conversions*
19. Environmental Review

*Not applicable to the NWMI construction permit application

Construction Permit Requirements

- Some regulations applicable to NWMI construction permit:
  - 10 CFR 50.22 (licenses for commercial and industrial facilities)
  - 10 CFR 50.30 (filing of application and Environmental Report)
  - 10 CFR 50.34(a), “Preliminary safety analysis report”
  - 10 CFR 20.1201, “Occupational dose limits for adults”
  - 10 CFR 20.1301 (public and accident dose limits)
  - 10 CFR 50.35, “Issuance of construction permits”
  - 10 CFR 50.40, “Common standards”
  - 10 CFR 50.50, “Issuance of licenses and construction permits”
- Per the ISG Augmenting NUREG-1537, 10 CFR 70.61, “Performance Requirements,” may be used by applicants to demonstrate adequate safety of a medical isotopes production facility
- 10 CFR Part 50, Appendices A, “General Design Criteria….,” and B, “Quality Assurance Criteria…,” apply to nuclear power and fuel reprocessing plants
- 10 CFR Part 100, “Reactor Site Criteria,” siting and accident dose criteria apply to nuclear power reactors and testing reactors

Construction Permit Application Contents

- Consists primarily of environmental report and preliminary safety analysis report (PSAR), as required by 10 CFR 50.30 and 50.34

- PSAR includes:
  - Preliminary design of the facility, including principal design criteria, design bases, general arrangement, and approximate dimensions
  - Preliminary analysis of structures, systems, and components, including ability to prevent and mitigate accidents
  - Probable subjects of technical specifications
  - Preliminary emergency plan
  - Quality assurance program
  - Research and development

Operating License Application Contents

- Must include final safety analysis report and supplement, if needed, to environmental report

- Must include final design and analyses that conform~~s~~ to the design bases of the facility as well as:
  - Plans for operation
  - Emergency Plan
  - Technical Specifications
  - Physical Security Plan

Construction Permit vs. Operating License

- Construction permit (10 CFR 50.35)
  - Allows licensee to proceed with construction based on preliminary design information
  - Does not approve of the safety of any design feature or specification unless specifically requested by the applicant
- Operating license (10 CFR 50.57)
  - Allows licensee to operate the facility based on final design
  - Issued when, among other things, construction of the facility is substantially completed in accordance with NRC requirements and there is reasonable assurance that the activities authorized by the license will not endanger the public health and safety

NRC Review Methodology

- Since construction permit only allows construction, level of detail needed in application and staff’s SER is different than for combined operating license or operating license applications
- For the purposes of issuing a construction permit, the NWMI production facility may be adequately described at a functional or conceptual level in the PSAR
- NWMI has deferred providing many design and analysis details until the submission of its final safety analysis report (FSAR) with its operating license application
- Staff’s review tailored to unique and novel technology described in NWMI’s construction permit application using appropriate regulatory guidance

Resolving Technical Deficiencies

- For technical areas requiring additional information, the staff has several options:
  - The staff may determine that such technical issues must be resolved prior to the issuance of a construction permit
  - The staff may determine that such information may be left until the submission of the FSAR
  - The staff may require that such technical issues be resolved prior to the completion of construction, but after the issuance of the construction permit
- In all cases, staff may issue requests for additional information
- In the second and third options, staff may track regulatory commitments or identify necessary license conditions

Tracking Commitments and License Conditions

- SER Appendix A
  - Appendix A.1 – Proposed license conditions
  - Appendix A.2 – Regulatory commitments identified in responses to RAIs
  - Appendix A.3 – Fulfilled regulatory commitments identified in responses to RAIs
  - Appendix A.4 – Commitments identified through meeting with the ACRS Subcommittee
  - Appendix A.5 – Ongoing research and development

Proposed License Conditions – Criticality

- Prior to the completion of construction, NWMI shall ensure that all nuclear processes are evaluated to be subcritical under all normal and credible abnormal conditions. This determination shall be done for each area as described in Section 6.3.1.1 of the NWMI PSAR prior to each area being completed, and shall be done consistent with the Upper Subcritical Limit (USL) established in Revision 2 of NWMI's Validation Report. NWMI shall submit periodic reports to the NRC, at intervals not to exceed 6 months from the date of the construction permit, summarizing any changes or indicate no change to the criticality safety evaluations as a result of the revised USL.
- Prior to the completion of construction, NWMI shall submit periodic reports to the NRC, at intervals not to exceed 6 months from the date of the construction permit. These reports shall provide the technical basis for the design of the CAAS or notify the NRC of no change. Prior to the completion of construction, the reports shall demonstrate detector coverage as defined in the requirements of 10 CFR 70.24(a).

Proposed License Conditions – Quality Assurance

- NWMI shall implement the quality assurance program described, pursuant to 10 CFR 50.34(a)(7), in revision 3 of the NWMI preliminary safety analysis report, including revisions to the quality assurance program. NWMI may make a change to its previously accepted quality assurance program description provided the change does not reduce the commitments in the program description previously accepted by the NRC. Changes to the quality assurance program description that do not reduce the commitments must be submitted to the NRC within 90 days. Changes to the quality assurance program description that do reduce the commitments must be submitted to the NRC and receive NRC approval before implementation.

- Similar to the requirements of 10 CFR 50.55(f) for implementing and changing an approved quality assurance program (applicable to power and fuel processing plant permit holders)

Appendix A.4 –Regulatory Commitments Identified Through ACRS Subcommittee Meetings

Date and ADAMS Accession Number for Correspondence	Description
September 18, 2017 ML17265A048	NWMI will provide an evaluation of the effects of high frequency spectral accelerations (i.e., > 10 hertz) on high-frequency sensitive structures, systems, and components during seismic events (e.g., electrical relays, instrumentation) in its FSAR.
September 18, 2017 ML17265A048	NWMI will provide details on the final grading of site, ensuring that stormwater from localized downpours will be directed around and away from the Radioisotope Production Facility (RPF), in its FSAR.
September 18, 2017 ML17265A048	NWMI will provide a final hazards analysis (FHA) for its facility as part of its FSAR. This FHA will re-examine those accident sequences that were screened out of the preliminary hazards analysis, ensuring that the FHA properly accounts for the accident sequences relevant to the final design of the facility.
September 18, 2017 ML17265A048	NWMI will provide an evaluation of the potential impacts of a uranium fire in the target manufacturing facility licensed under 10 CFR Part 70 on the RPF.
September 18, 2017 ML17265A048	NWMI will provide an evaluation the possible effects of damaged electrical equipment and resulting in possible unexpected effects of interaction between otherwise unrelated, independent, and separate circuits

Appendix A.4 –Regulatory Commitments Identified Through ACRS Subcommittee Meetings (continued)

Date and ADAMS Accession Number for Correspondence	Description
September 28, 2017 ML17283A108	NWMI will determine during RPF final design whether facility operations will use an on-site dedicated fire water supply and/or use the City of Columbia fire water supply.
September 28, 2017 ML17283A108	NWMI will resolve the discrepancy in the maximum estimated precipitation for the 24-hour and 48-hour period during the RPF final design and provide the information in the operating license application.
September 28, 2017 ML17283A108	NWMI will reexamine and ensure the accuracy of its estimates for aircraft take-offs and landings at the Columbia Regional Airport and for the surrounding heliports during the RPF final design.
September 28, 2017 ML17283A108	NWMI will provide its strategy for addressing an extended shutdown of the NWMI production facility during the final design.
September 28, 2017 ML17283A108	NWMI will further assess the need for an independent control room as part of our RPF final design.

Aircraft Impact Analysis

- ACRS Subcommittee identified errors in NWMI's aircraft impact analysis
- NRC Staff performed a confirmatory analysis
  - Total aircraft impact frequency calculated by the NRC staff is of the same order of magnitude as that calculated by NWMI
  - NRC staff finds that the applicant should evaluate the impact of a general aviation crash (greater than order of magnitude 10^{-7})
  - Errors identified include inconsistent flight operations, incorrect crash rates for specific aircraft, inconsistent non-airport crash frequency, transposition errors in crash impact probabilities, and incorrect runway bearings

Type of Aircraft	Impact Frequency (yr^{-1})	
	NWMI	NRC Staff
General aviation	1.78E-07	3.22E-07
Commercial air carrier	1.61E-11	2.55E-10
Air taxis	3.27E-11	4.38E-09
Military large	1.66E-08	2.60E-08
Helicopter	9.7E-07	5.1E-07
Airways	1.0E-06	1.1E-06
Total	2.2E-06	1.9E-06

Aircraft Impact Analysis (continued)

- SER Appendix A.4 - NWMI will reexamine and ensure the accuracy of its estimates for aircraft take-offs and landings at the Columbia Regional Airport and for the surrounding heliports

- NWMI commits to resolve the discrepancies in the data during the final design and will be provided in the operating license application

- The staff will further review the aircraft impact analysis in the FSAR as part of the OL application to ensure that these deficiencies are corrected

Status of the NWMI Review

- As of October 2017, NWMI has adequately responded to all requests for additional information
- NWMI PSAR Rev. 3 in ADAMS on September 14, 2017 (ADAMS Accession No. ML17257A019)
- Final environmental impact statement published in May 2017 (NUREG-2209)
- Safety evaluation report in concurrence and set for issuance in November 2017
- Mandatory hearing on construction permit application scheduled for January 23, 2018

Regulatory Basis for Construction Permit

- The following findings must be made to issue a construction permit, based on 10 CFR 50.35:
  - Facility design has been described, including the principal architectural and engineering criteria for the design
  - Further technical or design information as may be required to complete the safety analysis can reasonably be left for later consideration, and will be provided, in the FSAR
  - Safety features or components requiring research and development have been identified and there will be conducted a research and development program reasonably designed to resolve any associated safety questions
  - Safety questions will be resolved prior to the completion of construction and the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public
- Staff's conclusions also based on the considerations in 10 CFR 50.40 and 50.50

10 CFR 50.35(a)(1) Findings

- *Facility design has been described, including the principal architectural and engineering criteria for the design, and major features or components have been identified for protection of public health and safety*
  - Staff evaluated preliminary design to ensure sufficiency of principal design criteria; design bases; and information relative to materials of construction, general arrangement, and approximate dimensions
  - When necessary, staff issued requests for additional information and performed confirmatory calculations
- Staff finds that there is reasonable assurance that final design will 1) conform to design basis, 2) provide adequate margin for safety, 3) provide for the prevention and mitigation of accidents, and 4) meets applicable regulatory requirements and acceptance criteria

10 CFR 50.35(a)(2) Findings

- *Such further technical or design information as may be required to complete the safety analysis, and which can reasonably be left for later consideration, will be supplied in the final safety analysis report*
  - The staff evaluated the sufficiency of the preliminary design of the NWMI production facility based on NWMI's design methodology and ability to provide reasonable assurance that the final design will conform to the design bases with adequate margin for safety
  - Throughout PSAR and in response to RAIs, NWMI has indicated areas that require further technical or design information
  - Staff is tracking this information as regulatory commitments as identified in Appendix A of the SER.
- Staff finds that NWMI has provided reasonable assurance that further technical or design information, which can reasonably be left for later consideration, will be provided in the FSAR

10 CFR 50.35(a)(3) Findings

- *Safety features or components requiring research and development have been described and the applicant has identified, and there will be conducted, a program reasonably designed to resolve any safety questions*
  - NWMI has identified four ongoing research and development activities related to 1) irradiation and corrosion testing, 2) resin testing, 3) ion column pressure relief testing, and 4) evaluation of the release of diamylamylphosphonate from the ion exchange column during operation
- Staff finds NWMI has adequately described research and development programs
- Staff has determined additional information needed on certain matters related to nuclear criticality safety
  - Staff recommends inclusion of conditions in construction permit

10 CFR 50.35(a)(4)(i) Findings

- *There is reasonable assurance that such safety questions will be satisfactorily resolved at or before the latest date stated in the application for completion of construction of the proposed facility*
  - Latest date of construction completion proposed to be December 31, 2022
  - Based on research and development schedules, NWMI expected to resolve safety questions prior to completion of construction
  - Permit conditions must also be satisfied prior to completion of construction
- Staff finds that there is reasonable assurance that NWMI's research and development activities will be satisfactorily completed at or before the latest date for the completion of construction of the NWMI production facility

10 CFR 50.35(a)(4)(ii) Findings

- *There is reasonable assurance that, taking into consideration the site criteria contained in 10 CFR Part 100, the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public*
  - While 10 CFR Part 100 site criteria are applicable to power reactors and testing facilities, staff considered similar site-specific conditions in SER Chapter 2
  - Staff confirmed, in SER Chapters 11 and 13, that radiological releases during normal and accident scenarios would be within 10 CFR Part 20 limits based on review of applicant's use of 10 CFR Part 70 Integrated Safety Analysis methodologies
  - Preliminary emergency plan meets requirements of Appendix E to 10 CFR Part 50
- Staff finds that there is reasonable assurance that the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public

10 CFR 50.40 and 50.50 Considerations

- Based on the findings of 10 CFR 50.35 and the proposed license conditions, the staff concludes that there is sufficient information to issue a construction permit, as guided by the considerations in 10 CFR 50.40 and 50.50:
  - There is reasonable assurance: (i) that the construction of the NWMI production facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission's regulations
  - NWMI is technically and financially qualified to engage in the construction of its proposed production facility
  - The issuance of a permit for the construction of the NWMI production facility would not be inimical to the common defense and security or to the health and safety of the public
  - The application meets the standards and requirements of the AEA and the Commission's regulations, and notifications, if any, to other agencies or bodies have been duly made