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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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668TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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OPEN SESSION

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THURSDAY

NOVEMBER 7, 2019

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ROCKVILLE, MARYLAND

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B10, 11545 Rockville Pike, at 1:00 p.m., Peter Riccardella, Chairman, presiding.

COMMITTEE MEMBERS:

PETER RICCARDELLA, Chairman

MATTHEW W. SUNSERI, Vice Chairman

JOY L. REMPE, Member-at-Large

RONALD G. BALLINGER, Member

DENNIS BLEY, Member

CHARLES H. BROWN, JR. Member

VESNA B. DIMITRIJEVIC, Member
WALTER L. KIRCHNER, Member
JOSE MARCH-LEUBA, Member
DAVID PETTI, Member

DESIGNATED FEDERAL OFFICIAL:
CHRISTOPHER BROWN

ALSO PRESENT:
REED ANZALONE, NRR
BRIAN GREEN, NRR
JOSHUA KAIZER, NRR
NADIM KHAN, NRR
ATSUSHI KUMAKI, MHI*
ROBERT LUKES, NRR
SCOTT MOORE, Executive Director, ACRS
SHEILA RAY, NRR
JOSEPH TAPIA, MHI
GEORGE WUNDER, NRR

*Present via telephone

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P R O C E E D I N G S

1:05 p.m.

CHAIRMAN RICCARDELLA: (presiding) The meeting is in session.

MEMBER SUNSERI: All right. Thank you, Mr. Chairman.

So, today's presentation involves our review of the Design Certification Application and staff's Safety Evaluation Report for the MHI USAPWR. Our review today is the continuation of the DCA review that involves Chapter 8, "Electrical Power"; Chapter 18, "Human Factors Engineering Program", and a Topical Report on Advanced Accumulator.

We held an in-depth Subcommittee meeting review on September 19th with representatives from MHI and staff. And we are holding this meeting today to engage the full ACRS for the preparation of an Interim Letter Report of our review of the DCA and the staff's SER.

So, I understand that the staff, George, you have no opening remarks at this time?

MR. WUNDER: That's correct.

MEMBER SUNSERI: So, we'll turn to Joe Tapia of MHI.

MR. TAPIA: Thank you very much.

We'll start with the Accumulator, and the Accumulator --

MEMBER SUNSERI: Just one thing here to note. So, Joe is representing MHI, but we have a staff of people on the phone line listening in. Is that correct?

MR. TAPIA: Yes, there is a colleague on the phone line.

MEMBER SUNSERI: Oh, okay, a colleague.

MR. TAPIA: Yes, we've confirmed that.

MEMBER SUNSERI: Okay. Good. Go ahead.

MR. TAPIA: So, the green light is on.

MEMBER SUNSERI: The green light is on, yes.

MR. TAPIA: Okay. Great.

The advanced accumulator is an accumulator tank with a flow damper inside the tank that provides two stages of flow injection. It uses a passive fluidic device and is part of the Emergency Core Cooling System that is utilized during loss-of-coolant accident. The use of this accumulator into our LOCA mitigation strategy simplifies the ECCS configuration by elimination of a low head safety injection system, which is normal in a conventional PWR.

Our Topical Report that we're describing today includes all of the design characteristics, operational principles, design features, and testing programs that we conducted. And it also confirms the safety analysis model that is used in other chapters.

The accumulator itself is a vertical, cylindrical tank with a volume listed here of 3180 cubic feet. Its height is 30 feet. It's quite large. I have a picture of it later. The inner diameter is 12 feet. The design pressure is 700 pounds, and it's got two volumes, basically, inside for flow, large flow and small flow. And I'll go into that in more detail in just a moment.

This schematic shows the simplified structure of the accumulator, what we call the flow damper inside the tank. At the top, you see the yellow. That is nitrogen overpressure gas, and on the left you will see the standpipe. The basic concept is that the initial injection is, the portion of the blue below the nitrogen down to the top of the standpipe, that's the volume that's calculated for large flow. And after that, the standpipe no longer has any flow going through it. So, we switch over to small flow.

This schematic shows basically what happens inside of the damper itself. As I described,

on the left side we have large flow injection, which comes from the combination of the standpipe and the small flow pipe at the bottom connected to what we call the vortex chamber. Once that top volume is exhausted, we switch over to small flow injection, depicted on the righthand side.

For the large flow injection phase, the design requirement or performance requirement is that the lower plenum and downcomer of the reactor vessel be filled with water as rapidly as possible, and the required volume is 1307 cubic feet. For the small injection phase, the downcomer needs to be kept filled with water until the SI pumps take over injection. And the required volume there is a bit less, 724 cubic feet.

This schematic shows the simplified ECCS configuration. It shows the location of the accumulators which inject into the cold leg. There are four high head safety injection subsystems that follow after the accumulator injection. As you can see, there is no low head safety injection as the result of the use of this accumulator. And the size of this accumulator allows for water injection a lot longer than the conventional accumulator, and that allows for more time for the safety injection pumps to

start, which also allows us to utilize the gas turbine generators in lieu of the conventional diesel generators for power, emergency power. So, there are a couple of benefits from the use of our simplification design from the use of this accumulator.

MEMBER SUNSERI: Joe, I thought I heard you say the accumulators inject into the cold leg, but it's really direct-vessel injection, is that right?

MR. TAPIA: No, sir.

MEMBER SUNSERI: No?

MR. TAPIA: It's to the cold leg.

MEMBER SUNSERI: The cold leg? Oh, okay.

MR. TAPIA: If you could see the drawing --

MEMBER SUNSERI: Okay. I'm thinking about something else. Sorry. Yes, yes.

MR. TAPIA: High head is a different -- okay.

This explains the flow requirements and compares the normal conventional accumulator in the PWR, on the top, with our advanced accumulator on the bottom. And as you can see, the blue line on the top drawing shows the injection of a conventional accumulator. Once it empties, it rapidly declines;

the blue line goes straight down. And at that point in time, the red line indicates the required flow to maintain the design requirements for keeping the core sufficiently covered. What happens is that you need to have the low head injection during that phase before the high head injections come on.

So, with the use of the advanced accumulator, and as you can see, without the low head injection pump, the injection flow from the accumulator is in two stages, indicated by the blue line on the bottom right. We first have the large flow, and it switches over to a small flow portion, which still maintains the requirement or supersedes the requirement for maintaining the reactor core covered. And that allows removal of the low head injection.

And as you can see on the bottom on the timescale, that time allows for the use of gas turbine generators which need to be up and running less than 100 seconds, as opposed to a conventional diesel which is, I think, about 12 seconds or so for starting and running. We have a lot more margin, which allows the use of gas turbine generators.

So, we designed this accumulator in several steps. The first one was a development phase

where confirmatory tests were utilized, scale models that confirmed several aspects of it. One was the anti-vortex function to make sure that there was no vortexing, and that was a 1-to-3.5 scale. We also used a 1-to-8.4 scale to confirm the principles of flow. It basically has a plastic or glass underneath to confirm the flows. The 1/5th scale was done to better inform the actual conditions during the flow switching. And the design verification phase entailed complete, full-scale qualification tests.

This is a picture of the full-scale test. And just for illustration, if you see the two white signs in the front of the tank, those are about the height of a person. So, the tank is 30-feet tall. So, it's quite a large tank.

The design was verified with qualification testing, as I just illustrated, full-scale. As a result of that testing, the flow damper performance with both the small and large flows were verified as well as the flow switching. From that testing data, we were able to generate empirical characteristic equations for the flow coefficients to describe the flow characteristics, and that was utilized in our LOCA analysis, design analysis, to confirm compliance with all requirements.

So, as a conclusion, the accumulator has been fully tested and satisfies the design requirements.

MEMBER KIRCHNER: Joe, I suspect this thing really made a racket. I bet it vibrated pretty strongly. Did you also look at the structural supports, and such, needed to hold this thing in place when this happens?

MR. TAPIA: No, sir, that wasn't part of the qualification test.

MEMBER KIRCHNER: Yes, just hydraulic testing, yes.

MR. TAPIA: Yes, that was the performance testing. But you're right. I was there for the full-scale testing. It does make a noise, but the restraints in that test stand were adequate. We didn't see any problems. And I'm sure that the loading is included in the calculations for the support in the plant itself.

MEMBER KIRCHNER: Thank you.

MEMBER BALLINGER: There's another plant that has a similar configuration, if you want to call it that. And when they did the tests, Walt's prediction came true. They had huge vibrations, and it actually impacted design of the plant because it

was Walt's predictions were correct. They had huge vibrations and it affected the fatigue design of the plant.

MR. TAPIA: I understand. Again, we didn't experience large vibrations during the testing.

MEMBER BALLINGER: Okay. They did.

MR. TAPIA: Yes. Okay.

MEMBER BALLINGER: They did.

MR. TAPIA: Okay.

MEMBER BALLINGER: It's not exactly the same. The principle is the same, but it's -- the vortex thing was the same.

MR. TAPIA: Yes, of course, there are some large forces, but those will be incorporated into the support designs.

CHAIRMAN RICCARDELLA: I would think the real concern is support of those internal pipes --

MEMBER BALLINGER: Yes.

CHAIRMAN RICCARDELLA: -- as opposed to the overall vessel, but I'm sure it can be designed for.

MEMBER REMPE: So, during our Subcommittee meeting -- it's been a while since I've looked at this -- but it seemed like even your last sentence, it's applicable to the actual plant. And I believe your

Topical Report made reference to some of the parameters that were extracted for your design of the advanced accumulator based on the LOCA analysis that's documented in your submittal. And so, it is something that is dependent and very specific to your plant, or at least another plant who would come in would have to show, because we always think about these Topical Reports could be adopted by somebody with Joe's reactor. And so, there is a connection to the actual plant.

And the reason I'm bringing this up is I asked the staff why their SER didn't acknowledge that, somewhere in there, there should be -- I would have thought they would have some sort of limitation saying that the plant needs to follow up or the applicant needs to justify that it meets those specifications or characteristics that you find in this Chapter 15 analysis.

And I never heard finally back from the staff. Actually, I think what the staff did was they actually said, yes, you may be right. But when they get up, we're going to follow up with the question of, well, why didn't you do that? Because I don't think they did when I saw the updated SE.

MEMBER MARCH-LEUBA: I mean, the Chapter

15, we have to follow the local file of what they really install.

MEMBER REMPE: But sometimes we see in the Topical Reports that, when the staff does an SE, they have to say, hey, it's not just this is a wonderful advanced accumulator design. They actually need to have some sort of limitation that references it back to the design.

MEMBER KIRCHNER: Well, I think, Joy, my own opinion, not to answer your question on behalf of the staff or the Applicant, my own opinion is they can run these tests, and then, for the XYZ plant, you can look at what the demand curve is, which Joe showed in some of his figures. And then, you can say this particular accumulator at this size, and such, will supply the demand curve with margin, or whatever. And you can see it in the charts here. And then, it's fine. You know, it doesn't matter. It's the accumulator doesn't care what plant it's injecting into, so to speak.

MEMBER REMPE: But it has to have something that will meet that demand for a probability --

MEMBER KIRCHNER: Yes, but the demand curve is set by the Chapter 15 analysis. And then,

you would have to demonstrate, bringing this accumulator to the table, that it's going to supply the requisite flow -- stay below the demand curve.

MEMBER REMPE: So, we'll have to hear from the staff how they did that connection in their SE.

MEMBER KIRCHNER: Yes. So, where I was going with this, though, is I think that you could probably plug such a design into multiple PWR plants as long as you can demonstrate you're going to supply enough capacity.

MEMBER REMPE: So, there are no limitations -- and the staff can correct me, because maybe I'm wrong -- but when I looked through this information, which has been over a month ago and I may have made a mistake, but there was no limitation saying that this Topical Report is approved along as -- of course, the applicant would need to show they've met that, that they can do the probability --

MEMBER KIRCHNER: Yes, that I can't answer.

MEMBER REMPE: Yes.

MEMBER KIRCHNER: But I was just trying to suggest that this thing can stand on its own. It's a little bit different than -- I'll make up an example -- methods that are attuned to a specific fuel element

design with specific spacer grids, and so on. Because here all you want to do is demonstrate that you can satisfy the demand curve of flow.

MEMBER REMPE: So, maybe the SE does do that, but I expected there would be some sort of limitation that would reflect that.

CHAIRMAN RICCARDELLA: Your table indicated that the design pressure is 700 psig. What is the actual delivery pressure?

MR. TAPIA: Injection occurs at about 650.

CHAIRMAN RICCARDELLA: Six fifty? Okay.

MR. TAPIA: Yes, sir. And, of course, tech specs require pressure to be within a certain range.

MEMBER BLEY: Pressure that's in the nitrogen space?

MR. TAPIA: Yes, sir. And it's part of an ongoing surveillance required by tech specs.

MEMBER BLEY: Okay. Which is standard.

CHAIRMAN RICCARDELLA: And that's the same, regardless of whether it's the high flow or the low flow?

MR. TAPIA: That is correct.

CHAIRMAN RICCARDELLA: It's just the gas pressure.

MEMBER DIMITRIJEVIC: What's the high pressure, head pressure for high pressure injection in pounds?

MR. TAPIA: I'll have to get back to you on that, the high pressure injection value?

MEMBER DIMITRIJEVIC: No, what's the pressure --

MR. TAPIA: I don't know the exact number, but I can get back to you.

MEMBER DIMITRIJEVIC: That's all right. Okay. It's not so important.

MEMBER KIRCHNER: You can infer it from the curve. Oh, we don't have pressure. We don't have the pressure coastdown. If you had the pressure coastdown curves, then you can infer what the head is at the pumps.

MR. TAPIA: I'm sorry, this is flow. It's not pressure.

CHAIRMAN RICCARDELLA: But the yellow portion in that says, "high head pumps". I'm surprised that you need high head pumps that late in the transient. I would think you would need high flow pumps than high head.

MEMBER KIRCHNER: That's the conventional accumulator.

MEMBER DIMITRIJEVIC: They're both yellow.

CHAIRMAN RICCARDELLA: Well, they both have the yellow. The bottom one says, "high head pumps," too. Oh, it just says, "safety injection pump". Okay. All right.

MEMBER DIMITRIJEVIC: This says that the injection pump is a high pressure safety injection, right?

MEMBER KIRCHNER: Well, it's kind of medium.

MEMBER DIMITRIJEVIC: Oh, it's kind of medium?

MR. TAPIA: It's not the conventional.

CHAIRMAN RICCARDELLA: Six fifty.

MEMBER DIMITRIJEVIC: Oh, okay. All right.

MEMBER KIRCHNER: Yes, if you were to plot these curves on pressure, they're not quite the same. The high head injection pump is not the same as the safety injection pump.

CHAIRMAN RICCARDELLA: Yes. Okay. Thank you.

MEMBER DIMITRIJEVIC: No, no, it's sort of medium, the Reg Guide. That's what I was curious. I mean, you have a tragedy, which is your pressure.

MR. TAPIA: Yes.

MEMBER DIMITRIJEVIC: Then, you have this sensitivity sort of medium.

MEMBER SUNSERI: Okay. All right. If there's no further questions, we can move on to the next chapter.

MR. TAPIA: The next chapter is Chapter 8, "Electrical". Let's see. Oh, here it is. Okay.

Chapter 8 of "Electrical". Of course, we comply with Reg Guide 1.206 and the Standard Review Plan format, which is an offsite power description, and then, the onsite power, which is broken down into AC and DC, and then, station blackout. So, this is what I'll cover in this presentation.

The offsite power is conventional. It's two offsite sources with a normal preferred power from the reserve auxiliary transformers, and then, the alternate preferred power comes from the UATs through the main transformer. They're independent and physically separated, and both have a supply circuit which has the capacity for normal ops and for design basis events, to comply with all of the GDCs. So, that's pretty standard.

The onsite power is a little different. We have four trains of Class 1E AC electrical power,

and each train has a gas turbine generator as part of its emergency power source. These gas turbine generators are highly reliable and they're air-cooled as well.

The online maintenance, including concurrent with the single failure criterion, is satisfied. And permanent buses are also supplied by an alternate AC power source, which are also gas turbine generators.

And non-safety-related loads are electrically separated from the Class 1E buses. Required non-safety-related loads are supplied from these alternate AC power sources during a loss of offsite power. And the AACs also provide power to all station blackout required loads to bring and maintain the unit in safe shutdowns.

This is one line of the electrical system. And as you can see on the bottom, we have the four 50 percent capacity each gas turbine generators, safety-related, and then, the red ones are the non-Class 1E also. And they are diverse from the safety in that they are different design, separate design and manufacturers. So, those are diverse.

And the rest of it is pretty standard design.

Yes, sir?

MEMBER KIRCHNER: Do you fire these gas turbines with diesel or --

MR. TAPIA: Yes.

MEMBER KIRCHNER: -- a jet fuel or --

MR. TAPIA: Diesel, sir.

These gas turbines have a continuous rating of 4500 kW, in a short time 4950. That's two hours within 24 hours, in accordance with IEEE. And the rating for the generator is listed here, a power factor of .8 and 6900 volts. The starting time has to be less than 100 seconds.

And these gas turbine generators were tested in a testing program that complied with Reg Guide 1.9, IEEE Standard 387, and the Draft ISG-21. And that testing program was submitted in two parts. They're listed on the bottom, qualification and test plan. And the initial type test results were submitted in these two reports which the staff reviewed.

The initial type test included load capability testing; start and load acceptance testing, which was comprised of 150 start tests, and then, the margin test to demonstrate capability to carry most of your load step, which is plus 10 percent.

With regard to the station blackout, which is another section in this chapter, the basic concept for coping with the station blackout is the use of the alternate AC gas turbine generators. And the design basis utilizes the diverse AACs to minimize the potential for common-cause failures between the regular gas turbines. That's a distinction. The non-Class 1E AACs packaged with the gas turbine generator are connected to the 6.9 kV permanent bus. And they can be aligned to any of the four Class 1E buses in response to the station blackout. And they supply safe shutdown loads during the SBO coping period, which is eight hours. It is in accordance with the Reg Guide 1.55.

With regard to open phase, the MHI response to this bulletin, which was the famous Byron bulletin, is to provide detection and protection, and this chapter describes the single failure criteria, and then, lists COL and some ITAACs.

With regard to detection and protection for open phase, the detection systems are provided on the high side of the main transformer and the reserve auxiliary transformer, and they have redundancy, as seen here in the drawings. So, they're redundant protection systems.

The COL item details the design and surveillance requirements that need to be defined in the COL. And for the DCD, Tier 1, we have one ITAAC, which is to ensure that the design is adequate to protect an open phase conditioning with monitoring, detecting, and alarming in the main control room. And that's listed here on the bottom as well.

The supporting documentation that was submitted to the staff on Chapter 8 is listed here. We had an AC power system calculation standard, and the COL, as I listed before, the Qualification Test Plan for the gas turbine generator and the type test results for the generator itself.

During the Subcommittee meeting, the question was asked about reliability, and that number -- I looked it up -- it's 3.5 times 10 to the minus 4 for the gas turbine.

MEMBER DIMITRIJEVIC: For an hour? That's a liquid hour?

MR. TAPIA: Yes. Well, it's --

MEMBER DIMITRIJEVIC: It's not for it to start?

MR. TAPIA: It's for start. It's to start, yes.

MEMBER DIMITRIJEVIC: It's to try to

start?

MR. TAPIA: To start. Per request.

MEMBER DIMITRIJEVIC: Okay. And what's the hourly favorite?

MR. TAPIA: I'd have to get back to you on that. I don't know.

MEMBER DIMITRIJEVIC: All right.

MR. TAPIA: I don't know. Once it's running, it would be, you know --

MEMBER DIMITRIJEVIC: No, it's, I mean, a little better; I would say not. But most important is how it runs.

MR. TAPIA: Yes.

MEMBER DIMITRIJEVIC: All right.

MR. TAPIA: Okay?

MEMBER SUNSERI: Any more questions?

CHAIRMAN RICCARDELLA: Yes, let me understand. I'm sorry, I'm not an electrical guy. So, going back to the slide where you talk about onsite power system. It's slide 4. So, you have these 1E electrical gas turbine generators are different than the AAC?

MR. TAPIA: Yes, sir.

CHAIRMAN RICCARDELLA: Okay.

MR. TAPIA: If you look at this drawing

here --

CHAIRMAN RICCARDELLA: All right.

MR. TAPIA: -- on the bottom you can see the blue GTGs. Those are the safety-related that are taken into account in our analyses.

CHAIRMAN RICCARDELLA: Okay.

MR. TAPIA: The red ones are the non-Class, which are diverse in that they're a different manufacturer and are accounted for in the SBO, station blackout.

CHAIRMAN RICCARDELLA: Okay.

MR. TAPIA: And they're all 50 percent capacity. So, what you're looking here is 300 percent capacity for all those six gas turbine generators.

CHAIRMAN RICCARDELLA: And there's no diesels whatsoever?

MR. TAPIA: No, sir.

CHAIRMAN RICCARDELLA: I've always wondered why plants haven't been doing it this way for years.

MEMBER KIRCHNER: It ties into the accumulator, among other things.

CHAIRMAN RICCARDELLA: Ah, I see.

MEMBER KIRCHNER: And in the old days, too -- the technology for gas turbines is vastly improving

-- the reliability wasn't there and they could be cranky starting them up with diesel. That's why I was asking the fuel source.

CHAIRMAN RICCARDELLA: Yes.

MEMBER KIRCHNER: I mean, they're nice when you go with natural gas, but --

CHAIRMAN RICCARDELLA: Thank you.

MEMBER BALLINGER: You can't make a direct comparison between pounds of thrust in a gas engine and horsepower, but, generally speaking, these things are about four times the size of a 100,000-pound thrust gas turbine engine for an airplane. So, they're big. They're framed turbines that you would have in a --

MEMBER KIRCHNER: Like in a combined cycle plant.

MEMBER BALLINGER: Yes.

MEMBER SUNSERI: All right. If there's no more questions, we can move on to Chapter 18.

MR. TAPIA: Chapter 18. Okay, Chapter 18. I'll cover it in this manner: I'll talk about the supporting documentation that was submitted, describe our design-specific HFE program management plan, and then, I'll talk about the US-Basic HSI, and then, summarize.

These are all the supporting documents that were submitted. Well, this is the first page. On the top, you have the Human Factors Engineering Program Management Plan. That's Item 1. And below that, you have nine Technical Reports which -- I'm sorry -- eight Technical Reports, which are basically the implementation plans that provide the detailed methodologies that address the NRC's review criteria and ensure compliance with NUREG-0711.

We also submitted one Topical Report, listed there, Item 10. That Topical Report describes a Human System Interface System and incorporates the resolution of issues that were identifying using U.S.-licensed operators who were utilizing the US-Basic HSI simulator. The other two documents are supporting documents that were audited by the NRC staff as part of the review of this chapter.

So, the USAPWR-specific HFE program management plan was developed in accordance with the NUREG, of course. And its scope is listed here. It's that the design team organization enrolls, processes, and procedures the human engineering discrepancy process technical programs in the COL information. So, HFE activities completed within the scope of the APWR design, the program element methodologies

described in each of those implementation plans which are separate Technical Reports that I highlighted earlier. And those elements are going to be documented in the Results Summary Report as part of the program after implementation.

The USAPWR HSIS -- sorry for the confusion here -- is based on the application of the US-Basic HSIS, which is the generic monitoring, alarm, control, and computerized procedure technologies that are employed in the main control room. That US-Basic HSIS is what is described in that Topical Report, and I'll go into that in more detail a little bit later.

The generic HSI technologies of the US-Basic HSIS combined with the specific HSI inventory needed for the specific USAPWR design, that is what was used to create the USAPWR HSIS. So, the development process for that site-specific HSIS confirms or changes the HSI inventory to reflect those site-specific items for that design.

As part of all this, one of the fundamental design assumptions and constraints for that is that the plant can be operated with a minimum operation staff of one RO and one SRO in the main control room during all postulated modes. However, that's not what occurs in real practice. The staffing

is augmented in real practice with another RO and another SRO.

With regard to the generic US-Basic HSI which was utilized to develop the USAPWR specific human factors approach, that document was submitted as a Topical Report, and its foundational elements use the Japanese Basic HSIS as a starting point to create this U.S.-based HSIS which is described in the Topical Report. And it applies combinations of design review, redesign, and design validation through a phased implementation that occurred. Appendix A of that document contains all the information about the Japanese Basic HSIS and its development history.

Okay. As I described earlier, the normal main control staffing consists of one RO and one SRO, but they're supplemented in real life. And the space and the layout of the main control room can accommodate that augmentation of the additional SRO and RO during normal operations, as can be seen by this drawing. There are four chairs there that are the normal complement, two SROs and two ROs. However, the HFE analysis is based on just one SRO and one RO.

And the next slide shows a picture of the control room. It has several VDUs, large ones in the back and several at the operators' station. These are

four different kinds of VDUs, operational that execute all the normal plant control and monitoring functions, including the safety systems. We have separate safety VDUs for controlling the safety-related and monitoring functions, and, also, serve as a backup for the operational VDUs.

We have alarm VDUs to acknowledge and display individual alarms using prioritization color codes that were defined during this HFE analysis. And they also provide confirmation and non-confirmation information to the operators.

And finally, as a tool, operator tool, we have the operating procedure VDU, which is computer-based procedure displays near the alarm stations and operational stations to facilitate and simplify the performance of the operators.

So, in summary, the US-Basic HSIS -- I have to slow down to say this stuff; there's too many letters (laughter) -- well, it used the U.S. -- the development of the USAPWR HFE program utilized the US-Basic HSIS, which was developed, as I described earlier, in utilizing operator inputs.

The DCD has one COL item that requires the COL applicant to develop a Human Performance Monitoring Program, and then, there are two ITAAC

items in the DCD. After the HFE programs described in the Technical Reports are implemented, Results Summary Reports will be generated and will be submitted to the NRC for review. This is the standard process.

These are the two ITAAC items. The first one is verification of the HFE program by use of validation testing. And the second one is confirmation of the as-built condition of the control room. Pretty standard.

I like this drawing because it basically condenses everything I've tried to describe and mumbled through a little bit in one simple drawing. You take the Topical Report, which is the US-Basic HSI, and from that, you develop the plant-specific design application which is described in our Technical Reports that I listed. And then, after implementation, we submit the Results Summary Reports, and the staff will review those.

And that's how we addressed the HFE. Any questions?

MEMBER SUNSERI: One of the things I believe I heard and saw in the Subcommittee meeting on this topic was that the way Mitsubishi has approached this is, you know, in the application, it's really gone beyond what we normally see in a lot of the

applications, where we just see the plans, because you've had time to actually put the operators and get some implementation of those plans. And so, it's a more complete, I guess, program than maybe what we've seen before. Is that accurate to say that?

MR. TAPIA: I would say so. We've been working on this for a long time, about 10 years. And actually, we had a lot of help back and forth with the staff and were able to generate, as you say, more than the standard approach for defining the HFE.

MEMBER SUNSERI: It was also my understanding that the feedback from the U.S. operators that performed was substantial and provided good advancement to the design.

MR. TAPIA: That is true.

MEMBER BLEY: At one point, you folks told us -- this is a long time ago -- that you actually had emergency operator procedures in place, but you hadn't submitted them. Is that still the case?

MR. TAPIA: For the USAPWR?

MEMBER BLEY: Yes. You don't think so?

MR. TAPIA: I don't think so, no.

MEMBER BLEY: It's an old note. Somebody had said that at --

MR. TAPIA: No, sir.

MEMBER BLEY: Okay.

MEMBER SUNSERI: Well, then, if there's no more questions for Joe or MHI, last call, then we'll swap out with staff.

MR. TAPIA: Thank you very much.

MEMBER SUNSERI: Thank you.

And my colleague next to me has noted it's three o'clock a.m. in Japan. So, we appreciate the commitment there.

MR. WUNDER: Good afternoon, Mr. Chairman, ladies and gentlemen of the Committee. I'm George Wunder and I'm the Lead Project Manager for the USAPWR Design Certification Review. I'm joined here by members of the staff, Nadim Khan and Sheila Ray of Electrical Engineering, and Dr. Brian Green of Human Factors.

We'll be presenting the staff's finding on the Phase 4 review of the Applicant's Advanced Accumulator Topical Report and on Chapter 8, "Electric Power," and 18, "Human Factors".

Getachew Tesfaye did the staff review of the Topical Report, but since he's out of the office today, I'll be making his presentation. I'll do my best to answer any questions you might have, but if I don't know the answer, I'm going to have to punt and

defer the response.

Okay. A couple of years ago, MHI submitted Revision 5 of their Advanced Accumulator Topical Report. The staff prepared a Safety Evaluation. Rev 5 of the report is based on three small-scale tests and a full-height half-scale test. Computational fluid dynamics analyses were used to adjust for scaling effects. The staff's SER imposed increased uncertainties on the inputs for the LOCA analysis, for the high flow and low flow injection regimes.

The Committee approved Revision 5 with the increased uncertainties. The increased uncertainties account for use of the CFD analyses models to extend the half-scale test results to predict the full-scale accumulator performance.

Revision 6 of the report is based on the three previous small-scale tests and a new full-scale test. The full-scale test replaced a half-scale test and a CFD analysis was not needed to account for the scaling effects. Revision 6 also introduced a modified flow damper with a pressure equalizing pipe. The flow damper was introduced to remediate flow instabilities identified during the full-scale test.

The primary focus of the staff's review

was to make sure applicable regulations are still met. To do this, the staff confirmed the adequacy of the conclusions of the small-scale test in light of the full-scale test and evaluated the addition of the flow damper to the design.

Oops. Sorry. There they are. Already talked about them. Okay.

The staff concluded that the characteristic equations developed from the full-scale test which do not contain the additional uncertainties imposed by the Rev 5 SER are comparable to the Rev 5 tests with the computational fluid dynamic analysis. Staff also concluded that the characteristic equations developed from the full-scale tests are applicable to the full-scale accumulator.

And that's what I have to say. And now, I assume --

MEMBER REMPE: Do you want my question?

MR. WUNDER: Absolutely.

MEMBER REMPE: Okay. So, you heard me discuss it earlier.

MR. WUNDER: Right.

MEMBER REMPE: I've just been wondering how you have confidence, then, when an applicant comes in, not necessarily this design center --

MR. WUNDER: Right.

MEMBER REMPE: -- but someone else, that their widget will match up with this approved accumulator report. And I did bring up the document where you refer to the fact that uncertainties were based on analyses --

MR. WUNDER: Yes.

MEMBER REMPE: -- from Chapter 15 of the DCA.

MR. WUNDER: Again, from a project manager's standpoint, what we're doing is we're saying this component, this can deliver this demand. And when you're trying to say, is this going to work on my plant, then you have to do your Chapter 15 analysis. And to put a regulatory hook or something in a Safety Evaluation for the Topical Report doesn't seem to me to make any real sense.

MEMBER REMPE: Okay. So, when I asked the question at the Subcommittee meeting, I got a different answer. It was like, "Yeah, we probably should," is what I recall. And I can pull up the transcript and verify that. So, I was expecting something to happen after the Subcommittee meeting on this topic.

MR. WUNDER: No, in my discussions with

the -- and your memory may well be better than mine -- but in my discussions with the staff, they were pretty much confident that this was the right way to go.

MEMBER REMPE: Okay. Well, again, I just was a little puzzled because of the response I got. And perhaps you're right that it's just known that you're going to do that comparison, but what prompted the question was the fact that they refer to the Chapter 15 analyses as a way to characterize what uncertainties needed to be considered. So, there is a sentence in your SE, at least the version I have, which may have changed, that refers back to Chapter 15.

MR. WUNDER: It won't have changed.

MEMBER REMPE: Yes. But, anyway, if everyone else is happy -- I just remember asking a question.

MR. WUNDER: Okay. Any other questions?

(No response.)

In that case, I will move on to Chapter 8 and turn it over to Nadim Khan.

MEMBER BROWN: Excuse me. I don't remember asking this before years ago when we did this. It just now occurred to me on the accumulator. This is a giant tank, 30-feet high. The water is just

sitting in there forever while you're operating. The lower plenum area is that whatever you call the vortex generator with all the stuff going on --

MR. WUNDER: Yes.

MEMBER BROWN: -- and you're sitting there for years. Was there any consideration to any water purification or contamination or sediment buildup, such that it would constrain the flow and the buildup of the actual movement of the flow through that lower flat, pancake-like device?

MR. WUNDER: I don't know the answer to your question. I don't know.

MEMBER BROWN: I'm not even sure it's relevant. It's just I'm sitting here thinking you operate for a long time. Is there any V&V and of the type things? I guess my thought was, does it get flushed periodically or is it just Grade A reactor water the whole time, and it just sits there for 40 or 50 years and nobody cares? That's the wrong word. I didn't mean to say it that way.

MR. TAPIA: Joe Tapia.

MEMBER BROWN: Yes?

MR. TAPIA: This tank is an ASME tank.

MEMBER BROWN: I have no idea -- I mean, I understand what ASME is, but that doesn't mean it's

clean necessarily.

MR. TAPIA: Well, it requires, I think, every 10 years a complete inspection.

MEMBER BROWN: That's an internal inspection, is what you're talking about?

MR. TAPIA: Basically, it involves inspecting the tank visually and ultrasonic testing of welds. So, it's a Class 1 component. So, it falls under the ASME testing surveillance requirements. And the water is reactor grade and it's stainless.

MEMBER BROWN: Oh, it's a stainless steel tank?

MR. TAPIA: Yes, sir.

MEMBER BROWN: Oh, okay.

MR. TAPIA: So, I hope that answers your question.

With regard to inspecting and making sure that something like that doesn't --

MEMBER BROWN: Okay. When you said "inspected," I mean, I'm trying to wrap my hand around that. I mean, I'm thinking internal down at the bottom. You say every 10 years they're required to do -- I'm sorry for a minute. The computer people just told me I've got to put my pin in. It's not working.

MEMBER SUNSERI: We don't need to know

that, though.

MEMBER BROWN: I know, but I'm taking time away from their time. All right. Now I'm there.

So, that's where I was going with it. You say 10-year inspection.

MR. TAPIA: That's what I'm sure of. There may be other tech spec surveillance.

MEMBER SUNSERI: There's typically a flow test required at some periodicity of the plant. I don't know if it's five years or two, or something.

MEMBER BLEY: It might even be every refueling, but that's what I --

MEMBER SUNSERI: Yes, I don't remember doing them every refueling, but they're periodically.

MEMBER BROWN: You're going to have to lower the nitrogen pressure.

MEMBER KIRCHNER: And flush.

MEMBER BROWN: And flush.

MEMBER KIRCHNER: Refueling provides a way also of kind of cleaning out any potential debris that may accumulate, because you've got to depressurize the system, and then, depressurize the nitrogen overcharge, and cetera.

MEMBER BROWN: Well, it wasn't obvious how we flush it, that's all, because you've got the

initial surge down with the big standpipe, and then, you're coming up and out. So, it's not like you've got a drain at the bottom. It doesn't look like it.

MEMBER KIRCHNER: I don't know firsthand what their inspection procedures are, but it is, as Joe points out, covered on the ASME under the Boiler and Pressure Vessel Code. It's got to be at least a 10-year inspection interval, and that would include visual --

MEMBER BROWN: Internal visual inspections.

MEMBER KIRCHNER: Internal visual inspections.

MEMBER BROWN: Okay. I'm sorry. It was just something that occurred to me.

MR. TAPIA: That 10-year is a minimum I'm sure of. There may be other surveillances that are required by the tech specs. I'm not sure of that, but I think there are.

MEMBER BROWN: Okay. Thank you.

CHAIRMAN RICCARDELLA: I mean, I would say, other than this somewhat complicated flow device, it's no different than accumulators that are used in current plants.

MEMBER BROWN: It's that lower, the

generator, the little amplifier, if you want to call it, the vortex thing with the pipe coming in for the rest of the second level of flow that you're going to get. That's just a different layout than just a giant tank with a pipe at the bottom.

That's all. So, thank you. I'm done.

MR. WUNDER: Okay. We'll now move on to Chapter 8, and I present Nadim Khan and Sheila Ray.

MR. KHAN: Thank you, George.

As George mentioned, my name is Nadim Khan.

The USAPWR electric power system consists of the offsite power system and the AC and DC power system. During the staff's review, there were two open items. Both issues were closed in Phase 4. And today, we will discuss the open items and the resolution of these items. The open items are open phase condition and gas turbine generator reliability.

Next slide.

The first open item is regarding the open phase condition and the staff's position as outlined in BTP 8-9. BTP 8-9 discusses the electric power system design vulnerability due to an open phase condition in the offsite electric power system.

The staff requested that the Applicant

explain how its electrical system design would detect, alarm, and respond to an open phase condition. The Applicant provided a COL item in which the COL applicant is to determine the type of open phase detection and protection system and address the guidance in BTP 8-9.

The staff determined that the COL item will ensure that the COL applicant will determine an open phase detection and protection system that meets the guidance in BTP 8-9, including detection, alarm in the main control room, and protection feature, in that the Class 1E medium voltage bus will transfer to a power source without an open phase condition.

Therefore, the staff finds this issue closed.

Now I will turn it over to Sheila.

MS. RAY: Thank you.

And again, my name is Sheila Ray and I'll be presenting on the second open item, on GTG reliability.

MHI proposed the use of gas turbine generators and the Class 1E emergency power source for the onsite power systems. GTGs have not been used in the operating fleet as Class 1E power sources. Therefore, there is no operating experience and no

reliability data in nuclear applications.

In the absence of operating experience and reliability data, the staff requested the Applicant to perform type tests to ensure the GTGs will perform their intended function and achieve their target reliability level.

Next slide.

MHI discussed the qualification methodology in initial type tests for the GTGs in Technical Report MUAP-107024. Specifically, the type test includes load capability testing, start and load testing, and margin tests for IEEE 3871985, as endorsed by Regulatory Guide 1.9.

The Applicant documented the successful qualification of the Class 1E GTGs in Technical Report MUAP-10023. MHI successfully performed 150 start and load acceptance tests of the GTGs. The report demonstrated that the GTGs were able to start and be ready to accept load within 100 seconds, which is the GTG start time used in accident analyses. The successful start satisfied the reliability criterion of 0.975 with 95 percent confidence.

In conclusion, the staff finds that the Applicant's approach to demonstrating Class 1E GTG reliability is adequate, considering compliance of

GDC 17, conformance to Regulatory Guide 1.155, as well as successful qualification via type testing.

This concludes the staff presentation. Any questions?

MEMBER KIRCHNER: Sheila, just a minor point. On slide 4, I think what you're implying in that second bullet is that there's no operating experience with 1E, Class 1E, equipment.

MS. RAY: In nuclear power plants.

MEMBER KIRCHNER: Yes, yes. But there's a lot of gas turbine experience.

MS. RAY: Correct. Absolutely. There is a lot of gas turbine --

MEMBER KIRCHNER: Yes. So, it's just implied. Thank you.

MS. RAY: Uh-hum.

CHAIRMAN RICCARDELLA: Could I get a comment from our PRA folks as to, you know, there's 150 tests; gets you .975 reliability with 95 percent confidence?

MEMBER DIMITRIJEVIC: Do you want me to calculate this in this moment now?

CHAIRMAN RICCARDELLA: No. I mean, is that in the right ballpark?

MEMBER DIMITRIJEVIC: Well, I just want to

say this is a system that the deterministic requirement, in my opinion, from this GDC 1.17. So, they have their principles. I am not even familiar with this requirement. I mean, you know, I was wondering how does this experience with gas turbines in the industry. And they said, the staff, the data they gave me backed up this. So, I wasn't really requiring to check the validity of this, you know.

CHAIRMAN RICCARDELLA: Okay.

MEMBER MARCH-LEUBA: Although 56 tests with no failures gives you 95/95.

CHAIRMAN RICCARDELLA: Oh, really? Okay.

MEMBER MARCH-LEUBA: Yes, and this is the .975. So, 150, the fact that you're wrong here, I'm sure it's not 150. It's either 147 or 152.

CHAIRMAN RICCARDELLA: Yes, okay. I understand. That's all I wanted, was, is it in the ballpark?

MEMBER MARCH-LEUBA: Oh, it is.

CHAIRMAN RICCARDELLA: Yes. Okay.

MEMBER MARCH-LEUBA: And you can more tests without one failure. Like what we did yesterday with the --

CHAIRMAN RICCARDELLA: I see. This is 150 tests with no failure.

MEMBER DIMITRIJEVIC: I think no failure, right, right.

CHAIRMAN RICCARDELLA: This is like binomial distribution or something like that?

MEMBER MARCH-LEUBA: This is called no parametric statistical testing or something.

CHAIRMAN RICCARDELLA: Okay. Thank you.

MEMBER BROWN: Can I provide an observation? The Navy must have about 500,000 of these installed in the DDG-type ships. All of their electric power in all recent -- there's no steam turbine. There's no steam systems for the last 30 years just about. And they operate all the time.

The biggest issue on the GTGs was the startup time and being able to load them. They can't do it in 10 or 12 seconds the way you can diesels, but you, with the design of the plant and the systems that you've got, the 100 -- what did you say, 100 seconds? And that's more than enough time for those to come and be ready to be loaded.

That's based on -- they're not in the nuclear plants. This is in the non-nuclear plants, but we were aware of everything they were doing, and I also worked on some of that post-retirement with the non-nuclear Navy. So, they work very well with

reasonable information.

MEMBER SUNSERI: Well, thank you.

And, George, I guess we're ready to move on.

MEMBER BLEY: Yes, well, before you do --

MEMBER SUNSERI: Okay.

MEMBER BLEY: -- I looked up the NUREG on surveillance testing. If you have valves -- do they have valves in their accumulators? On other PWRs, they do have valves. And there, you would normally have a quarterly test, except they're exempt. These valves are exempt and you have to test the valves every time you go into cold shutdown. And my memory is, when you do it, you have somebody watching the accumulator level, and that's how you know those valves are really open.

MR. WUNDER: Thank you.

And for our final presentation, we move to Dr. Brian Green.

Brian?

MR. GREEN: Good afternoon.

You can go to the next slide, and you can even skip that one and we'll go right to some conclusions here. We wanted to make sure we weren't going to kill you with PowerPoint slides today.

Mr. Tapia gave a real nice presentation about how the application was set up. So, I'll just focus on the staff conclusions.

Staff reviewed the Topical Report MUAP-07007. Staff found that it describes an acceptable generic platform, referred to as the US-Basic HSI, or HSIS, as the Applicant calls it. If we couldn't make this any more complicated, we have one set of acronyms to describe the same thing and they have another one. So, I apologize if I forget the second "S" there.

After that, the implementation plans have been provided, produced in iteration on the US-Basic HSI. Staff has found that this will be consistent with the state-of-the-art human factors principles and applicable regulations that would apply.

Staff also found that the ITAAC are an acceptable means to confirm that the HFE practices are incorporated into the final design. And there are no open items at this time or confirmatory items.

MEMBER SUNSERI: Anybody have any questions for staff?

MEMBER BROWN: Yes, I wanted to go backwards. On the open phase detection system, I'm trying to remember what we talked about in the

Subcommittee meeting.

It's literally been put off based on the BTP and into the operating COL period. And I can't remember whether I asked this question or not. Who gets involved in that review of the completion or satisfactory compliance with the BTP requirements when it's actually developed by a COL five, six, seven, eight, nine years from now? Is it just a site inspector involvement with the applicant or the licensee or does staff get involved in assessing whether that's satisfactory, whether they ended up with a satisfactory system? I mean, I recognize we don't know what it looks like. How's it going to be reviewed by the top level at that time?

MS. RAY: I understand. So, when the COL application comes in, the electrical staff at NRC will review the compliance with BTP 8-9, which will essentially show compliance with GDC 17. So, electrical staff will review it.

MEMBER BROWN: Okay, but will there be some -- as part of that review, does that include not just the fact that they're going to do it, say they're going to do it? Does that include some actual looking at what the design looks like and the testing that's being required, or something like that? I've just

forgotten what's in the BTP.

MS. RAY: It would depend on the design.

MEMBER BROWN: Okay. So, there's some involvement --

MS. RAY: Typically, what we have done -- and I can give you some experience what we have done for South Texas Project 3 and 4.

MEMBER BROWN: Okay.

MS. RAY: We did look at their analyses. They did load flow studies to show that the detection would pick up an open phase. And we looked at their protection as well to see how that would pick up an open phase. So, we did look at calculations and studies to verify --

MEMBER BROWN: Were there any actual tests as opposed to just calculations done at South Texas?

MS. RAY: Not at --

MEMBER BROWN: They never got there?

MS. RAY: Because it wasn't built yet.

MEMBER BROWN: Yes.

MS. RAY: So, it's just the design phase.

MEMBER BLEY: And it will never be built.

MEMBER BROWN: No, I understand. Yes, I understand that, based on what's going on.

MS. RAY: However, there was an ITAAC.

MEMBER BROWN: That would have operation and actual tests?

MS. RAY: Correct.

MEMBER BROWN: Okay. Oh, all right. I forgot that. Thank you.

MS. RAY: Right. And the protection side, if it was a Class 1E protection, there would be tech specs.

MEMBER BROWN: Okay. Thank you.

MS. RAY: Uh-hum.

MEMBER SUNSERI: Any others?

(No response.)

All right. While I ask for the control booth to open the phone line, I'm going to turn to the audience and see if there's any members of the audience that want to make a public statement. Come to the mic; state your name; make your statement.

(No response.)

None?

All right. Now I'm turning to the open phone line. If there's any members of the public on the open phone line that would like to make a statement or a comment, please do so now. State your name and provide your comment or statement.

(No response.)

All right. No comments or statements coming in on the public line.

So, that concludes our presentation, Mr. Chairman, on the USAPWR application. We are prepared to discuss a proposed Letter Report at your leisure on the agenda, according to the agenda.

CHAIRMAN RICCARDELLA: Well, we have another topic coming up at 2:30, NUREG knowledge management on credibility assessment for critical boiling transition models.

Do we have time to do a read-through of the letter before that? Do you agree? Would you like to do that?

MEMBER SUNSERI: If that's allowed, I think.

I guess I did miss asking if there were any statements. Nobody wants to make anything? Yes, right. Yes.

Yes. Chris, are we ready for -- we can do a read-through.

MEMBER REMPE: If you can't switch out the computers, just hand out the hard copies, right?

CHAIRMAN RICCARDELLA: Yes.

MEMBER REMPE: Okay. Let's just do it that way.

CHAIRMAN RICCARDELLA: Yes, that would be fine.

MEMBER SUNSERI: And I want to thank the staff and Mitsubishi for their great presentations today and good interaction during the Subcommittee as well.

MEMBER REMPE: Do you have them separated, so they can do it?

CHAIRMAN RICCARDELLA: Yes.

MEMBER REMPE: Oh, that's wonderful.

MEMBER BALLINGER: Is he off the record right now or not?

CHAIRMAN RICCARDELLA: Yes, I think, yes, he's off the record.

MEMBER BALLINGER: Off the record, but we will be back, for 20 minutes or so.

CHAIRMAN RICCARDELLA: Until 2:30.

(Whereupon, the foregoing matter went off the record at 2:12 p.m. and went back on the record at 2:34 p.m.)

CHAIRMAN RICCARDELLA: Okay.

MR. KAIZER: Good. Good afternoon. My name is Joshua Kaizer. I work in the -- sorry, we just changed our title -- so, it's Nuclear Methods Fuel Analysis Branch in NRR, and this is Reed

Anzalone.

MR. ANZALONE: Reed Anzalone. I'm in the Nuclear Systems Performance Branch.

MR. KAIZER: And we are here to talk about this credibility assessment framework for critical heat flux and critical power models.

So, when we were going through the slides, one of the first things Reed said was we wanted to give you some type of background, some motivation. So, that's what these textbooks are for.

I started with the NRC in 2006. And when I got here, this was pretty much the textbooks I had. Most of them were forced on me by Larry Hochreiter at Penn State: Collier and Thome, Todreas and Kazimi. A couple of them I picked up this year. It's actually an autographed copy of Graham Wallis' One-Dimensional Two-Phase Flow, the BWR textbook, and then, the Hewitt and Hall Taylor for film boiling. And then, Tong and Tang for CHF.

And I had all of these textbooks and I had all of this knowledge about thermal hydraulics in general, but what I didn't have was knowledge of, okay, that's great, but how do you do code review, because my Branch forever was called Nuclear Performance Code Review. How do you review a code?

And I wanted a textbook in that area. I never really found one.

The closest I got, because I frequent old bookstores too much, was this Philosophy of Auditing by the American Accounting Association. And I read part of it and it's not really that great. It was kind of there but not really.

(Laughter.)

So, when I got to go back to do my dissertation, I actually got to write what I considered. So, my dissertation became a NUREG. I call it "The Fundamental Theory of Scientific Computer Simulation Review". And the idea was this was more of a textbook on how do you do code review.

And in that process, I discovered that a lot of people have obviously thought of it before, but I now had the words to actually go back and look at it. And so, a big motivation for this framework came out of applying what the NRC sent me back to learn into this one particular area of critical heat flux and critical power.

Why that area? We had a really smart guy named Tony Attard who had been in this area for a long time and he was retiring. And we were trying to capture that knowledge. We had a number of reviewers

that started doing these reviews and, shock of shocks, they were learning the same things that Tony Attard had taken years to learn and they had to relearn them and said, okay, is there a way to make this faster?

I will admit that, when we started this effort, the main object was to increase objectivity. I wanted the same review for every CHF correlation going out there. That is nice, but it also helped that increasing efficiency was, let's say, a natural byproduct, but that was also, I think, the big seller: hey, if you go through this type process, it will make your life a lot easier.

And the cool thing is we have real objective evidence to show that we've had pretty much the same review done with and without the NUREG. And with the NUREG, it takes less than 50 percent of the time. It's even smaller than that of how much in time savings this is.

Basically, my motivation here, we wanted to create a textbook on how perform a specific type of review. So, this basically is just going to walk through our NUREG. It's forming chapters.

The first chapter introduces the idea of credibility and credibility assessment frameworks. Then, it's a literature review. We give the

framework, the summary.

The interesting thing to me about this outline is, when creating this NUREG, we wanted to create one that could be easily replicated. We're coming up with one for CHF. That's great, but there's other problems with CHF. So, we tried to create it, when we made the framework, okay, you should be able to take this and apply it to any area, LOCA, fuel thermal-mechanical. You name it; it should go in here.

And we also tried to base it similarly to a dissertation because we wanted a little bit more of that "researchy feel". So, like the literature review and technical background is Chapter 2, having a detailed explanation by the staff; trying to put all the references in there, which is really helpful. We'll talk about that later, too.

So, first, again, please feel free to stop me or ask any questions.

MR. ANZALONE: Oh, yes, and I guess one thing I would point out, when we were developing this presentation, we were trying to figure out, well, what's the best way to structure how we're going to talk about this. And because the NUREG itself provides such a structured approach to performing a

review, we thought it made the most sense to just walk through that.

MR. KAIZER: Yes.

MR. ANZALONE: So, that's how we're going to approach this. We're just going to walk you through the NUREG and how it works.

MR. KAIZER: So, first is "Introduction to Credibility and Credibility Assessment Frameworks". This is a fun name. A lot of these slides come from ASME verification and validation presentations I've given over the years. Credibility is this new term. I think the first people that actually coined it that I've seen were NASA in the wake of the Columbia disaster. They had a big presidential board that looked and said, hey, how can we go back and better determine that we can trust simulations? And they came up with that term "credibility".

Credibility is basically, in a general definition, it's a determination that an object can be trusted for its intended purpose. That's what it is high level. Generally, that object for us is a model or simulation, and the intended purpose is whatever we're using it for in safety analysis.

It's interesting because most of verification and validation, and certainly

quantification, is focused on credibility, but no one really talks about it. So, all of these are standards. In textbooks that talk about it, it's actually the main focus, but they don't ever bring it up. In this case, we're saying, okay, now we are talking about credibility. Validation feeds into it. Uncertainty quantification feeds into it. Because, ultimately, what we really care about is, can we trust the simulation for whatever its intended purpose is?

And this is where I think the history of the ACRS comes in. These frameworks, it was really by -- so, the second one was produced at Sandia. And it was a guy named Marty Pilch. Marty was actually heavily influenced in the nuclear sector, heavily influenced by CSAU, got to work with Novac Zuber. And then, he left the commercial world and started working in Sandia for like atomic weapons research. And he became head of Sandia's V&V program.

And so, he took everything he had from CSAU and that highly-structured approach, and he pretty much applied that there and came up with another structured approach that was, I'd say, a little broader than CSAU. Like CSAU was really good, but they like restrict it to this is for a LOCA analysis. Well, it could be for any analysis. They

worked out a really nice framework for it.

And so, Marty took that and made that, and that was later derived by a guy named Bill Oberkampf into Predictive Capability Maturity Model. NASA came up with a similar type of framework. And the most recent one is ASME V&V 40 that FDA came up with a very similar framework to determine the credibility of -- for them, it's a small medical device. That is what they really wanted to focus it as. But they're trying to have simulations that support those small medical devices.

So, these are just examples of common frameworks to say this is not really a new thing.

CHAIRMAN RICCARDELLA: What does CSAU stand for?

MR. KAIZER: CSAU, Code Scaling, Applicability, and Uncertainty.

CHAIRMAN RICCARDELLA: Thank you.

MR. KAIZER: I don't know if you know Kumar at Brookhaven. He was one of the main authors of that as well. He's got a lot of cool stories, too.

MEMBER MARCH-LEUBA: Kumar has been a consultant for this Committee, Kumar Roharkie (phonetic). Don't ask me spell it.

MR. KAIZER: So, what is a framework?

Well, it's pretty much you have some list of -- the traits of these are they each have these criteria. It's generally a small number of criteria. These are the things you have to look at. And then, you have different evidence levels. How good are you in each of those criteria? That's what the framework is.

So, these are some high levels of the NASA framework which I give because I don't think they're really useful, but it was out there. Verification, this is the questions they asked: were the models implemented correctly? What was the numerical error of uncertainty? And you rank that between 1 and 4. Validation, how did you compare against data? You rank that between zero and 4.

This is, to me, kind of the Holy Grail of decisionmaking. The atomic weapons people really wanted something like this because you had the experts who were your PhDs, and they needed to communicate to the decisionmakers, and the decisionmakers just wanted that single number, but the experts would do anything but give you the single number. So, they tried to come up with a system like this.

To the best of my knowledge, it did not work very well. To the best of my knowledge, almost all the methods I talked about earlier -- CSAU, it

does work. It's intensive, but it works, and it's how I think we do a lot of our regulation today, how we structure it. So, that's good.

PCMN, when it was initially applied, it didn't work. DOE has modified it and they have some ideas of making it work, but not for decisionmaking. The NASA standard I haven't heard anything about, and ASME V&V 40 hasn't been tried yet.

MEMBER BLEY: Pete, when we hear people, the thermal hydraulics guys especially, talking about best estimate with uncertainty, they are usually talking CSAU.

MR. KAIZER: Yes, sorry about that.

CHAIRMAN RICCARDELLA: When you say that V&V 40, is that part of NQA-1?

MR. KAIZER: No. NQA-1 is not an ASME standard. I think it's an ANS standard.

CHAIRMAN RICCARDELLA: ASME -- you say ANS?

MR. KAIZER: Yes, it's a different area. ASME, the American Society of Mechanical Engineers came up with a -- you know what ASME is. They came up with a whole verification-validation committee. There's 10, 20, 30. Thirty is the thermal hydraulics one. So, you've seen Hassan is on that one. He's

their current chairman. The NRC has a couple of reps.

The 40 --

CHAIRMAN RICCARDELLA: I'm familiar with the ASME --

MR. KAIZER: Okay.

CHAIRMAN RICCARDELLA: -- Code Committee, Section 3/Section 11, and they have some V&V standards.

MR. KAIZER: Yes, this was pushed off into its own committee group of people.

CHAIRMAN RICCARDELLA: Okay.

MR. KAIZER: And it's actually a lot of the same people from the National Labs.

MEMBER PETTI: Because it's not thermal mechanical. It's not thermal mechanical-based. It's more thermal hydraulic.

CHAIRMAN RICCARDELLA: Yes.

MR. KAIZER: It was what you just talked about, but it was really thermal mechanical.

CHAIRMAN RICCARDELLA: V 30, V&V 40.

MEMBER PETTI: There are different ones for different subject areas.

MR. KAIZER: Yes, they try to span all of verification-validation, which maybe I'll talk about that later. That's fine.

So, anyway, this is what the current levels look like. This is how we've changed it a little bit. So, there was this thing that was developed in the early 2000s in England -- I think it was literally like 2000 -- called Goal Structuring Notation. All it is is a beautiful way to understand an argument. And the idea is they standardized it. It was used in the Department of -- well, I think it's the Ministry of Defense over there. It was used in their -- I did talk with their -- their naval reactors is Rolls Royce because Rolls Royce controls all the subs. And their Rolls Royce program used it a little bit. They use is very high level; we use it much lower level. But, I mean, it works; it's pretty basic.

You have some high-level goal. You have some two low-level goals. The idea is that satisfying this is equivalent to satisfying these two. So, these are both necessary, and together they're sufficient for that to be true. It's that simple.

And we had come up with a similar notation we were using, and we were like, well, these people developed this beautiful notation; we're just going to adopt it. And that's Goal Structuring Notation, and that's how the NUREG is pretty much laid out.

MEMBER MARCH-LEUBA: What I like about this notation is -- it's probably not complete. It's very difficult to make it accurate, but it's all detailed.

MR. KAIZER: Yes.

MEMBER MARCH-LEUBA: You make your decisions ahead of time before doing the review.

MR. KAIZER: Yes.

MEMBER MARCH-LEUBA: And you document it. And somebody who has a problem with it can go and review what it is.

MR. KAIZER: Yes. One of the things -- I'll show you the big chart later. I have it behind me. The reason I love this notation is, when I have to give a presentation to -- let's say I have a problem with something and actually show it to the Office Director. It's going to be extremely hard for me to get my Office Director to learn all parts of thermal hydraulics to the point where they can now confidently say, hey, I understand what Josh is saying.

But when I break it down in this notation, I've just got to, hey, do you agree that, if that's true, those two are true? "Yeah, yeah, yeah." And you go down the tree. And that's what we'll do a

little later. We'll show you how to go down one of those trees. So, we can go over that.

This is the simple example I give of a complete credibility assessment framework. Is it safe to drive over a bridge? I'll try to stay over here. I'm going to say, okay, I'm going to say it's safe if the bridge can withstand the weight of my car and, also, if there won't be a natural disaster while I'm driving over the bridge. And I'm presenting to you that, if those two things are true, then it's safe to drive over the bridge.

Now, at this point, you can say, well, hey, you're missing something. Okay, great, I can add it. But, now at least when I say it's safe to drive over the bridge, you know exactly what I mean. I'm saying the bridge can withstand the weight of my car; there won't be a natural disaster while I'm driving over the bridge.

The second thing is, okay, the bridge can withstand the weight of your car. What levels of evidence can you provide? Here, the evidences are ranked zero through 6. I've talked with people at Sandia, and one of the hardest things that managers don't understand in this area is that these are not numbers with magnitudes. It's called an ordinal set,

where level 1 is less mature than level 2, but we don't know by how much.

MR. ANZALONE: But it's not half as mature.

MR. KAIZER: Yes, it's not --

MR. ANZALONE: It's just they're ranked.

MR. KAIZER: It's just less.

MR. ANZALONE: There's no magnitude associated with it.

MR. KAIZER: Yes. So, you know it's less; you know it's more; you don't know how much.

So, basically, what can I do; the bridge can withstand the weight of my car? Well, I don't think about it. Or maybe a little more evidence, I say, hey, somebody's probably checked it. Or I say, well, now I drove over it yesterday. As you increase the levels, you become more and more confident that your statement is true.

And it's the same thing with G2. Now what we purposely did in G2 was we added No. 4, which is it's an impossible level to reach. A time traveler came from the future and confirmed no natural disasters occurred on the bridge for at least 100 years. If that actually happened, that would certainly prove that there won't be a natural

disaster.

And having those artificial evidence levels is really helpful because it's kind of like when you put zero or infinity in your equation; you see where you're going. It gives you that asymptote. What are we actually aiming for? Initially, I was going to say a guy in a blue box, but I just didn't know how many people were Doctor Who fans. So, I said time traveler.

But that is a quick idea of what a credibility assessment framework is. And it's simple. I'm sure there's other names for it. I'm sure people have used it potentially elsewhere. I haven't seen it. But it's really basic.

So, with that, the rules for the framework. You start with some main goal you want to figure out. You logically decompose that main goal into other subgoals, where those set of subgoals are necessary and sufficient. And then, you just repeat that decomposition until you can't figure out any more subgoals. Then, you provide evidence.

So, for example, here --

MR. ANZALONE: Or maybe you can figure out ones that are below that, but --

MR. KAIZER: Yes.

MR. ANZALONE: -- you decide that you've gone far enough.

MR. KAIZER: Yes. So, here we could have decomposed G1 into other subgoals, and then, provided evidence for each of those.

MR. ANZALONE: Right. The bridge can withstand the weight of my car could go down to the level of like these bolts are designed to meet the standard. The beams that are composing the bridge were manufactured to blah, blah, blah.

MR. KAIZER: We probably shouldn't have picked a bridge.

(Laughter.)

MEMBER DIMITRIJEVIC: Do you have anything that probabilistically analyzes this?

MR. KAIZER: Yes.

MEMBER DIMITRIJEVIC: It's exactly the same thing. Here you will have end gate instead of all gate because it will be that big. So, you have end gate and you break it down until you have data for --

MR. KAIZER: Yes, this is --

MEMBER BROWN: And you have qualitative measures at the bottom.

MR. KAIZER: Exactly.

CHAIRMAN RICCARDELLA: What were you talking about, exactly compared to --

MEMBER DIMITRIJEVIC: Approaches in the PRA.

CHAIRMAN RICCARDELLA: In the fault tree.

MR. KAIZER: Yes, the difference between -- because, I mean, I've read at least some of the stuff by Apostolakis. Where they will combine levels in PRA because they can add stuff, we say, no, it's independent. It's like those are pressures; these are temperatures. You just can't add pressure to temperature to get 150 pressure kelvin pascal or something. So, I mean, again, yes, it shows up everywhere, and a lot of people use it. And it's just trying to write up, okay, how do you do this. I mean, it's logic.

MEMBER DIMITRIJEVIC: But what is missing in this approach is, look what you said, and they both have to be satisfied.

MR. KAIZER: Uh-hum.

MEMBER DIMITRIJEVIC: But you have a situation where BAN (phonetic) or Advec (phonetic) has to be satisfied, as you were saying. You don't have a way to express this with a simple --

MR. ANZALONE: Yes, and I've thought a

bunch about this, and I think that's one of the shortcomings of this approach, is that it can make it difficult in situations where you have like conservatisms in one place that are offset in another place. You can't leverage that. This can drive you to say this needs to be complete and this also needs to be complete. But, really, you should be weighing them together holistically. I feel like that could be a shortcoming of this.

I think it's addressed by recognizing that, you know, you can leverage two different things together and consider them in like an integrated fashion. But you have to be thinking about it that way to do it.

MEMBER KIRCHNER: Well, you have to be careful here, too, because -- I'm going to pick on this a little bit. on the lefthand side, you have deterministic. On the righthand side, you have probabilistic. Think about it. So, you're saying you can't add P and T together, but you've got really two different things here. But it's okay. It works. It works.

CHAIRMAN RICCARDELLA: There's a low likelihood of a --

MEMBER DIMITRIJEVIC: Yes, and also,

connectible has a different meaning in risk assessment. A credible accident is not high probability, not so awful big that it's incredible. Incredible is upper size, which is completely different.

MR. KAIZER: Yes, that's totally not the same kind of meaning that we're using here.

MEMBER DIMITRIJEVIC: And also, in this structure you wouldn't see your No. 4 on the right side. Actually, it could be the only thing satisfying everything. Because if you have a time traveler which can confirm that that bridge never collapsed, you don't have to worry about anything else.

MR. KAIZER: Yes. Yes. I guess I'll have to change what the time traveler says.

(Laughter.)

MR. ANZALONE: You don't want to know how many times we iterated on the examples.

(Laughter.)

MR. KAIZER: Yes, initially, I had the bachelor example that an unmarried male was a bachelor, but that was kiboshed by someone.

The other important thing that I forgot to mention here was, with these frameworks, you need to come up with a situation that satisfies all possible

inputs. So, in other words, if you're driving over -- like it is safe to drive over a bridge. This is probably a determination you make almost every day if you drive. Now if you drive over a bridge, you might ignore it. But, all of a sudden, you're driving in northern Michigan and you hit the Mackinac Bridge which is three miles, you might start thinking, gee, is it safe to drive over this?

So, you're going to use some version of this framework, and you might ignore some of these. And so, it has to be able to be used for that bridge, but, then, it also has to be able to be used for like, if the U.S. military is transporting a nuclear weapon, they're probably going to be looking at these lower levels. They're going to look for a recent inspection of the bridge. And so, it's all that you have to be able to address every time someone drives over it.

MR. ANZALONE: And there are clearly things that aren't addressed -- sorry, I'll let you talk in a minute -- but there are clearly things that aren't addressed in this framework or in this particular example, like it doesn't say anything about the safety of the car that's driving over the bridge.

MR. KAIZER: Yes, the other passengers, yes.

MR. ANZALONE: That is something that you would need to add. And you start thinking, well, when did I last have my tires replaced, stuff like that.

MEMBER PETTI: But, also, it seems like you need to -- in trying to figure out what's the right level, it seems to be a function of how close or how far away you are from something bad happening, right?

MR. KAIZER: Yes. Yes.

MEMBER PETTI: So, if you have margin, you might be willing to accept level 3 and don't have to go to level 6.

MR. KAIZER: Absolutely, yes. And your level question is actually a really good one. So, we talked about that.

MR. ANZALONE: I think we'll get to that.

MR. KAIZER: Yes, we'll definitely get to that.

The literature review background, the only thing I wanted to say about the literature review was, earlier when I said this NUREG was useful, if, for no other reason, than we actually provide a list of every CHF and critical power Topical Report that the NRC has ever reviewed. It took a very long time to compile the list. And a lot of those Topical Reports we put

in ADAMS our self because we had to request it from Records, and it was like 1980-something, and put it in. So, that was really awesome.

And I think that having that list for like all of the LOCA methods and all of the fuel thermal-mechanical methods would be an amazing resource.

MEMBER REMPE: Are you going to update it? I mean, we still review CHF.

MR. KAIZER: Yes. The idea is that, I mean, because it's a NUREG/KM, we can update it. The other reason of making it a KM was getting it out there, so people can look and say: hey, do you agree? Did we miss anything? Do we have anything that doesn't need to be there? The idea is that you would update this at some basis. And also, it is a lot easier to find the more recent documents in ADAMS than it is to find the ones from like 1973.

MEMBER REMPE: But it would be nice to have it updated, though. Ten years from now, we'll say, "Ah" --

MR. KAIZER: Pretty much, I agree.

So, the technical background, we give a discussion of the relevant phenomena, a discussion of how the phenomena is modeled. I like writing these areas because it's not extremely explained well in

these books because these books focus on the phenomena explicitly, and you're trying to talk about how it's happening in the actual reactor in the fuel bundle. And so, we can listen to the experts in the industry or we can write up how we think it's going to work, and then, ask the industry, hey, you guys should comment on this. And if we didn't tell it right, because this is our understanding, you should let us know.

So, that I think, for us, was a good verification that, yes, we understand how this is happening. We understand how all the modeling is working. We understand at least the current ideas of how CHF and critical power occur. So, that was really fun; and also, how the model was applied.

Chapter 3, the framework itself. So, I'm going to give you a high level and we're just going to walk down one path of this framework. So, the high level was the Critical Boiling Transition Model can be trusted in reactor safety analysis. We say that this is true if these three subgoals are true: experimental data supporting the model is appropriate; the model was generated in an acceptable manner, and the model has sufficient validation.

So, did we miss anything? Can you think

of, no, you missed this one thing where you also need this other category? So far, we haven't come up with anything.

So, we go from G; now we're going to go down to G1, the experimental data supporting the model is appropriate.

MEMBER MARCH-LEUBA: Will this help you define or recommend the range for applicability?

MR. KAIZER: The range of applicability of the model?

MEMBER MARCH-LEUBA: Yes.

MR. KAIZER: This has it in there. I mean, like we --

MEMBER MARCH-LEUBA: I mean, it's good between pressures of 100 and --

MR. KAIZER: Yes, it's one of the criteria. Because we use the range of applicability to say, first, I think in G1 -- no, in G3, we say you have to define the range of applicability. And then, we say, okay, prove to me that you've validated your model over the entire range of applicability and the uncertainty you've established --

MEMBER MARCH-LEUBA: Are those going to show up in lower levels?

MR. ANZALONE: Yes.

MR. KAIZER: Yes, that does show up lower levels. I don't know if it's in this example.

MEMBER MARCH-LEUBA: I was thinking that -- I meant the top level, but --

MR. KAIZER: Oh, okay.

MEMBER MARCH-LEUBA: That's what he was telling you, that this focuses your thinking and you can discuss and agree or disagree or improve it.

MR. KAIZER: Uh-hum. So, the experimental data supporting the model are appropriate. So now, what does that mean? Well, that means the experimental data have been collected at a credible test facility. They've been accurately measured, and the test bundle reproduces the local conditions in the reactor.

Okay. Now we break it down again. Well, what does it mean the experimental data have been correctly measured? And now, we break it down one more time.

Before I talk about these individual ones, it's generally a good idea, when you break these goals down, to not have too many levels, not have too many subgoals, and not have too few. There is a 1950s psychology paper, and I think it's "The Magic Number of 7 Plus or Minus 2". And they talk about how you

generally want -- it's like less than 5 and you don't have enough; more than 9 and it's too many. So, that's kind of what you shoot for for each breakdown. So, here we just happen to have six; sometimes we have three. It is what it is.

Anyway, the experimental data has been accurately measured.

MEMBER KIRCHNER: Less than 10.

MR. KAIZER: Yes.

MEMBER KIRCHNER: Definitely less than 10.

MR. KAIZER: So, what does it mean the experimental data have been accurately measured? Well, it means the test facility has an appropriate quality assurance program. The example we're going to look at is the experiment has been appropriately statistically designed, statistical design of experiments.

We're saying, also, the method used to obtain the critical boiling is accurate. The uncertainties of the instruments have been addressed. The uncertainty in actually calculating CHF, because they do it a very specific way, has been addressed. And then, you've also established your heat losses.

So, again, this is one of those. If all six of those are true, then I'm going to call that

experimental data has been accurately measured; that's true.

And finally, this is just a discussion of the statistical design of experiment. When you're looking at a statistical design of experiment, you need to ensure that the experimental methods don't introduce any statistical bias. So, Box, Hunter, and Hunter, which is the classic book on this, which I didn't realize that. Like John Stuart Hunter, there's all these cool YouTube videos of him teaching about it, and he actually gave the class first to Westinghouse. And there's like a seven series of Westinghouse books all on statistical design of experiment.

Anyway, you do the random sampling. Make sure that you randomize your input parameters. Almost all the methods in statistics assume a randomization of your initial conditions of experiments.

In CHF testing, the one thing you don't have is a randomization of your initial conditions because you have this big metal structure and it takes a lot of energy to move it from certain pressures and mass flow rates and temperatures.

MR. ANZALONE: And it takes a long time to heat up and cool down.

MR. KAIZER: Yes.

MR. ANZALONE: You can cause the seals at the top and bottom of the assembly to leak, which will cause you to have to shut down the whole experiment.

MR. KAIZER: Yes.

MR. ANZALONE: There are a lot of issues with having a truly random set of data.

MR. KAIZER: So, here we have to actually account for that. And we do account for it in other areas, but that's the thing we're worried about.

And this kind of goes back to the question earlier about what level do you use and what level is necessary. That's a really tricky question. And I think the way we actually addressed it in the NUREG is really good. We came up with the NUREG. We came up with the levels. And then, we said, what level is necessary or what level do we currently use? And if you go out and you figure out how you've made this decision already, that's probably the best guess for that's probably the best level going forward.

And so, here we just came up with four levels. And I think that we have a discussion in each NUREG about all the historic evidence levels that you would see looking back, thanks to our Office of OGC, which provided, I will have to admit, OGC provided

amazingly good comments on this, and not just like legal comments, technical comments. They had two lawyers, Robert Weisman and Julie Ezell, phenomenal comments. Now they know a lot about CHF, too, which is interesting.

So, anyway, these are the levels. Obviously, ideal. All system parameters were completely randomized. You don't really have that -- so, we basically identified, okay, well, which level? Is it 1? Is it 2? Is it 3? Is it 4?

I'd say in the NUREG, we identify the level. When you actually write this in an SE, you don't just say, oh, it's level 3. You generally just provide a justifications of how you know this goal has been met. So, it is usually like level 2, level 3, but we say, hey, that's acceptable because we've done it this way before.

MR. ANZALONE: And I think one of the things that you might be concerned about, if you were looking at this and you said, okay, well, our NUREG says level 3 is the most common, well, does that mean that that's what we expect? Not necessarily. It means that, if you have less than level 3, well, you might need to beef up the justification or the documentation compared to what we've seen before.

MR. KAIZER: Yes.

MR. ANZALONE: If you have more than level 3, maybe you don't need to do as much. So, it's a little bit fuzzier and subjective.

MEMBER PETTI: It's also a function of margin.

MR. KAIZER: Yes.

MEMBER PETTI: The closer you are --

MR. KAIZER: Yes.

MEMBER PETTI: -- the more you need.

MR. KAIZER: Yes.

MEMBER PETTI: Right?

MR. KAIZER: So, here we just say, yes, we just talk about level 3 is the most common.

This is what the entire -- it's an eye chart, but I just want to throw it up there -- this is what the entire framework looks like. To me, it's interesting because each of these areas, if you're going to learn about all these areas in total, it takes a long time to actually just grasp them all. But if I have to have an office director understand a specific issue, I can get down to my little one area and have them become not an expert on it, but understand it enough that they're not just relying on me. They understand why it's an issue fairly quickly.

We just did that here. And that, to me, is an extreme benefit, to have your senior management not just fighting for you because they think you're smart, but fighting because they understand why it's an issue.

So, here is this beautiful framework in all its glory. We printed it out. If anybody really wants to see, it's the largest printout I've ever had. It's like 4 feet. It's really cool.

And our future work. So, future work, this is what I'm working on right now for ASME standards. There's nothing special about critical heat flux and critical power models. They're data-driven models. This whole framework, it took us a long time to develop it, but what we really came up with was a credibility assessment framework for all data-driven models. You have to go in and you have to adjust the levels a little bit, but, ultimately, CHF models live and die by the empirical data. Data-driven models live and die by the empirical data.

We even stole language from machine learning, training data, validation data, k-folds testing, all that great stuff, because it just works so well. And so, right now, there's two ASME subcommittees that are getting together, and we're basically trying to turn this into one for data-driven

models.

One of the participants in the ASME standard group is actually using this for their data-driven model. It's not CHF. It's got nothing to do with nuclear safety. But they're using it, and it's like in a manufacturing areas, because it just works for data-driven models. So, that's what we're trying to do.

I would really like to, if I picked one for the future to develop, it would be the one for fuel thermal-mechanical models, because I see that as an area where we're seeing --

MEMBER MARCH-LEUBA: This is the computer model or the results?

MR. KAIZER: For the data-driven model?

MEMBER MARCH-LEUBA: No. This is --

MR. KAIZER: Sorry.

MEMBER MARCH-LEUBA: Oh, you're talking about a fuel thermal-mechanical correlation?

MR. KAIZER: Yes, a fuel thermal-mechanical correlation or code. It would be interesting. I'd like to take on that challenge.

MEMBER MARCH-LEUBA: Or taking TRACE?

MR. KAIZER: Yes.

MEMBER MARCH-LEUBA: You would, then,

apply this to TRACE? You would apply it to the correlation --

MR. KAIZER: I would love -- so, that's why that last one is grayed out, large break LOCA models -- I would love, and it's actually one of the goals I'd like to have before I retire. I would love to have a framework for just modeling and simulation in general. You have a code; use this framework.

MEMBER MARCH-LEUBA: To validate it?

MR. KAIZER: Yes, to demonstrate that you can trust it. And I think that you can get there. Because this framework, it pictures like, I think, how people think -- I mean, I think people naturally think in this. It's necessary and sufficient, and they break it down, because it's based on set theory, and most people use sets when they're considering stuff.

CHAIRMAN RICCARDELLA: When you say "data-driven," do you mean models for which there really isn't a strong theoretical basis?

MR. KAIZER: Yes. Yes, data-driven models are models where you only believe them because you have some empirical data.

CHAIRMAN RICCARDELLA: I think in terms of like a finite element analysis, a stress analysis model, there's theory behind it.

MR. KAIZER: Yes. Yes. So, this would not be --

MR. ANZALONE: Directly like empirical correlations.

MR. KAIZER: Yes.

CHAIRMAN RICCARDELLA: Yes, yes. Thank you.

MR. KAIZER: Yes, so they used to call them empirical correlations, but, then, the empirical correlations people hired an advertising company, and they're like empirical correlations was so 1800s; call them data-driven models now.

MEMBER MARCH-LEUBA: Because it's the same thing, right?

MR. KAIZER: Yes. So, yes, I would really love to see one of these for just all of modeling and simulation. I mean, I think we've proven with CSAU that you can do it. I think it needs to be refined. And there are a number of other people -- Nam Dinh at NC State does a lot of work like this. There's a lot of engineers that see this and they're like, wow, this makes so much sense. You're going to have to do this going forward. How else can you process all of this information? And so, there is this natural push to do a lot of this stuff.

MEMBER PETTI: Yes, I would probably argue, though, that the application into the different fields, there's a different cost driver, right?

MR. KAIZER: Yes.

MEMBER PETTI: I mean, to do this for CHF is one thing. To do it for another part of nuclear safety could be cost-prohibitive.

MEMBER REMPE: Well, on the other hand, though, when we were talking about what to do about this expanded power-to-flow thing that we wrote or we just approved a letter for, I think a lot of the agency processes could benefit from such a framework. You're going to have to rethink up through the levels, but -- I was going to wait until your last slide. But I think they've got to do things that are sort of repetitive, but it takes a lot of -- you know, they know the tricks and what to check. And the people who do it are going to retire. I think it's a good thing to encourage.

MEMBER MARCH-LEUBA: Yes. I love the fact that it's a knowledge management, a knowledge transfer.

But what got me to thinking about this was, just as you were showing the D5 correlation, we were reviewing Reg Guide 1.99, which we saw today.

And how does this model work, this assessment, if you happen to have 188 points to develop a correlation, and 20 years later you have 2,000 points, and the correlation doesn't work anymore?

CHAIRMAN RICCARDELLA: Well, it has some inaccuracies.

MEMBER MARCH-LEUBA: No, let's see what --

MEMBER REMPE: You weren't so good at extrapolating that data, is what I would say.

(Laughter.)

MR. ANZALONE: I was thinking about this last night because I was trying to think about the benefits and the shortcomings. And I've already talked a little bit about what I think one of the shortcomings is of this framework. But one of the big benefits is that you are going into explicit detail about why you found something to be acceptable. And if you collect more data that invalidates that reason that you found something acceptable, you have it there in black and white, the basis for your decision. And you can go back and say, I can refute this point now. We need to like call this into question and take a look at whether we really believe that anymore. So, that, to me, is one of the strongest components of this, is that it allows for that kind of

retrospection.

MEMBER KIRCHNER: I'm just thinking of other nuclear applications first. Probably the biggest data-intensive-driven set is ENDF. Have you thought through how this notionally would work there? And have you compared how they -- because that's international. And so, I'm not sure of all the rules for entering new cross-sections and how you prove that it's statistically valid, and all the things that you would use to come up with a credibility assessment. But, anyway, have you thought of some of the things that are in the mission space of the agency? It might be a good place to look first.

MR. KAIZER: We haven't applied this to ENDF. Where we have roughly applied it is to just other code reviews in general. I mean, again, CSAU, I would argue that this is very much in the vein of CSAU. So, almost all of our code reviews do this somehow. I think this is just a refinement of it.

MR. ANZALONE: I would say for nuclear data specifically, like we think the high-level goals are still probably where we would want them to be, but the lower-level ones maybe you would need to take a look at. I don't think that we've explicitly thought about it, but --

MR. KAIZER: Yes. Right. We've been explicitly trying to get -- because, right now, we just had comments, and I'm still addressing the comments. Nothing major. It's just I had a bunch of them, and then, I had other work assigned. So now, I'm trying to get back to it.

So, I do want to go to the last slide. We wanted to talk about the surprises. The surprise that came, I'd say, most shocking was that it works and how well it works. I have written things like my dissertation, which was great for me, but not really useful for many other people. But this really worked. I mean, it was very awesome to know that all these people have come up with these frameworks before, but we came up with a framework, and then, within a period of like two or three years, we've applied it four or five times.

And in one case where we could actually have a close measure, because, I mean, usually it was Reed and I applying it. But there was a lot of authors. We were the main authors.

But we had one case where we had someone who had a very strong background in thermal hydraulics do a review of CHF, and we know how long that took that person. And we had someone else who also had a

very strong background in thermal hydraulics do another review of CHF correlations, but they had this NUREG. And it took that person under 50 percent of the time, and it was significantly under 50 percent of the time.

And it makes sense because the first person had to learn everything from scratch because a lot of the CHF stuff, it's not captured in these textbooks. And they had to learn it. The second person had the benefit of this, and it's like, oh, okay, yes, check, check, check, check, and it went quick, really quick.

I've used this framework, I mean, now to write Safety Evaluations in, I'd say, under a week, because I can get it down to, wait a minute, I understand now; I just need to prove G3 is true. So, I just grab that whole set and say, okay, demonstrate how I've satisfied all these subgoals. Done.

MEMBER REMPE: So, for advertising purposes, it's great to say you saved resources, but I would emphasize it reduces regulatory uncertainties.

MR. KAIZER: Yes.

MEMBER REMPE: The applicant knows what you're going to be looking --

MR. KAIZER: Yes.

MEMBER REMPE: You're establishing the groundrules.

MR. KAIZER: Yes.

MEMBER REMPE: And that was why we really liked it when we first saw it, is that it wasn't a proprietary document that's couldn't be shared.

MR. KAIZER: Yes.

MR. ANZALONE: Now that it's out there, we're able to have those conversations with the fuel vendors about what the expectation is for them to submit stuff.

MEMBER MARCH-LEUBA: And then, they have an expectation. Their submittal takes half the effort.

MR. KAIZER: Yes.

MEMBER REMPE: It saves their resources, too. But that's not supposed to be something you're advertising.

(Laughter.)

MEMBER MARCH-LEUBA: Twenty-five of the RAIs.

MR. KAIZER: Yes.

MEMBER MARCH-LEUBA: Because you probably don't have to even issue RAIs anymore because they're going to answer your questions. They know what you're

going to ask.

MR. KAIZER: The one I'm really waiting for, there's apparently a new CHF correlation coming in, and I would be interested to see how closely they follow this. Because if you do follow this framework really closely, it should not take long at all.

And there's this weird tendency as a reviewer, when you have something, to want to hold onto it for months. Even if you look at it and don't think about it again, you feel like, if you look at it and say, oh, yeah, that was good, and then, sign it out right away, you haven't done your due diligence because you haven't thought about it. But, at least with this framework --

MEMBER MARCH-LEUBA: If they give you work and you do it in a week after they give you the TR, they'll say, "Aw, he didn't do the work."

MR. KAIZER: Yes. But, with this framework, you feel like, well, I've actually thought about it ahead of time. And one of the things I'm a proponent of is you should be able to write your Safety Evaluation before the report ever comes in. Because if you can't tell me what you need for a specific Topical Report to be considered safe before you see it, then, after you see it, you're just

reacting to subjective things. There should be some objective standard, and that's what we really like.

MEMBER BLEY: So, your ordinal scale, I'm not concerned about those. I think those work pretty well.

MR. KAIZER: Uh-hum.

MEMBER BLEY: Your completeness issue is one that, of course, you can add it when you find it later, but when you find it later, it may be because something went really wrong.

MR. KAIZER: Uh-hum.

MEMBER BLEY: So, you know, I've got to fix it. The same thing you bring up in PRA all the time. Your initial simple model of the bridge, now the bridge has collapsed because of vibrational modes, and, you know, that wasn't in there.

MR. KAIZER: Yes.

MEMBER BLEY: And so, somehow reinvestigating that you are complete across the range of things you need to check for is important. I don't know how you structure to that.

MR. ANZALONE: I guess to that, I would say, for this particular framework, we have enough history and experience that I think we can say we're comfortable that this is probably about as close to

complete as it's going to get.

MEMBER BLEY: You base that on reviews that have been done before without it and that you've covered everything that is in those reviews.

MR. ANZALONE: Exactly. But the challenge, then -- and I think you're exactly right -- comes in addressing, if we expand this kind of framework to other areas that maybe the agency has less experience dealing with.

MEMBER BLEY: I guess one more. The thing on the ordinal scale that could eventually be troubling somewhere is that, as you say, it's not a quantitative scale. One, two, and three might all be about the same effect and something else might be much bigger, and there's no sense of that, which might lead you to focus more effort on less important things. And I don't know what you're doing with that.

MR. KAIZER: Basically, the framework, even though you give the one, two, three four, it ends up being very binary. Either you've demonstrated that you've satisfied that goal or you haven't. And so, you have to come up with, okay, is level 3 enough; is level 2 enough? And people are always worried, oh, you're taking the engineering out of it. Not really.

MEMBER BLEY: No, you're organizing it.

MR. KAIZER: We're just trying to focus it. Yes, the engineering comes in with, is level 2 enough, is level 3 enough, and why?

MR. ANZALONE: Yes, that's exactly where engineering judgment comes into play.

MR. KAIZER: Yes.

MEMBER BLEY: And is your set complete? And when the individual sits down to do it, his or her sets may or may not be complete, depending on how good they are at thinking, at searching for those kinds of problems.

MR. ANZALONE: And while the shorthand for the framework is that big picture that he showed, there's a narrative along with it that says, like when we've seen this level of evidence historically in the past, this is why we've felt it was acceptable. When we go through the phenomenal logical review in the beginning, that's sort of laying out why we think that this set of goals is complete.

MR. KAIZER: Well, the only modification I would say is I'm convinced that this set of goals is not complete because I would love to prove from first principles that this is perfect, but outside of some mathematical things, as soon as you enter the engineering world you can't.

But what I actually have now is anyone that wants to can look, and it's like, okay, if it's not complete, tell me where. So, it might not be complete, but at least I get it out there in front of all the experts and they can provide feedback and say, wait a minute, you forgot about this: in 1957, this Russian thing happened, and blah, blah, blah.

MEMBER BLEY: The reviewer using this won't forget the ones you have here.

One quick question.

MR. KAIZER: Uh-hum.

MEMBER BLEY: I'd like to have that picture. The KM has all the pieces of the picture.

MR. KAIZER: Okay.

MEMBER BLEY: Given that it's electronic, you could put the whole picture in there.

MR. KAIZER: At a page? Yes. It would look like this, some slightly --

MEMBER BLEY: Now my copy of the KM looks like the thing you said is your thesis. Yes.

MR. KAIZER: This one?

MEMBER BLEY: No, mine has the same picture --

MR. KAIZER: So, then, you probably printed out my thesis.

MEMBER BLEY: Okay. It says, "KM-006" on it.

MR. KAIZER: Yes, 006 is the thesis.

MEMBER BLEY: Oh, what's this one? What's this one?

MR. KAIZER: Thirteen, yes.

MEMBER BLEY: Thirteen?

MR. KAIZER: Yes.

MEMBER BLEY: Oh, okay. And it's a KM?

MR. KAIZER: Yes.

MEMBER BLEY: Okay. I didn't grab that one. Okay.

MEMBER REMPE: So, to follow up on your thing about completeness and your comment about this is a general framework, and then, just life experiences -- we've had lots of confidences in the past in nuclear power, and then, learned, oh, we didn't think about that. Maybe it's worthwhile having another box that says any new information that could be -- push the person who's using this to force them to say, "I looked and I didn't see anything else." I mean, you said it's in your narrative, but maybe is it in there strong enough, is where I'm kind of going.

MR. KAIZER: I think because of the way the framework was, I would put that in like an

introduction section. Because, I mean, I don't know if you would want that like next to each and every goal.

MEMBER REMPE: Maybe not in every goal, but maybe somewhere at the top just about new things. Somehow, make sure that they've checked that box. Because if they go to apply this --

MR. KAIZER: Yes.

MEMBER REMPE: -- and I'd like them to try and apply it other places, but we've had a history where we didn't think -- severe accidents are always something we didn't think about.

MR. KAIZER: One of the areas I would like to get to, which I think will be awesome, is if there is a way to quantify an uncertainty measure with how comfortable are we with this breakdown -- like do we have a lot of experience saying G1.1, 1.2, and 1.3 are equal to G1? Are we like, yes, we know this or, you know, this is an area where we have high uncertainty, but this is the best we have? And how to even incorporate uncertainties correctly in this? I mean, I think that's also that part of it. It's like, okay, this was based off of old information.

MR. ANZALONE: Almost going back to like a PERT.

MR. KAIZER: Yes.

MR. ANZALONE: Like what's the state of knowledge on this particular aspect?

MR. KAIZER: Yes.

MEMBER REMPE: Something. I'm wondering. It's been a long time. We didn't meet for a month, and I think I looked this over when you guys did it earlier. So, I didn't spend time re-reading it.

MEMBER PETTI: I think what you're arguing is the unknown unknowns.

MEMBER REMPE: Yes, and just to make people check the box that I really am thinking outside the box here. If you've got a process, it would be real easy to have that ground engineer to say, oh, I don't have to do anything else; I did this process. And I make him think.

MEMBER BLEY: But you've got to always be pushing to think of new things. But the good thing here is you've thought about it pretty well against what's been done in the past. And whoever uses this is likely to be more complete than they would have been on their own.

MR. KAIZER: Yes.

MEMBER BLEY: And if they come up with something new, it would be real good if you have some

mechanism to really coax them to talk to you.

MR. KAIZER: Yes.

MEMBER BLEY: I mean, theirs would be better, but the overall system wouldn't have gained from that.

MEMBER MARCH-LEUBA: It's a small enough community that they would be talking about it.

(Laughter.)

MEMBER BLEY: We say that, but we don't always do that.

(Laughter.)

MEMBER REMPE: Some of the observations about the fuel failures and trying to understand what occurred, it's just there's always new information out there. And if this sits on the shelf -- and again, also trying to give the applicant realistic expectations. This is the process we're going to use. You had better address this stuff. But we'll both be looking to see if there's anything new we ought to consider.

MEMBER DIMITRIJEVIC: I want to say something. Everything that you said, in short, PRA has, Probabilistic Risk Assessment has 40 years of experience. Everything is totally identical to what I heard in the beginning of development of the PRA.

However, PRA has 40 years of experience. So, a million questions. And even if it's identical that you carry, because I used to carry the model for failure of status of the water system developing, exactly which means that it goes around the walls. And everything that you want to accomplish and everything what you think can be accomplished, that's called the story of the PRA beginning. It's totally identical. It's actually spooky.

I was listening to you. And now, you're starting some completely new application which has to be, you know -- this is not quantitative, PRA is totally quantitative. So, there is a way to put uncertainties in. You know, there are questions which also brings it so that the PRA will be completely applicable. The questions then is all applicable.

Even we have standards now which have four categories, which is completely similar to your numbers 1, 2, 3, 4, you know. The limits of this is that you cannot show quality of results or uncertainty, and how close are the results to the reality, and what is the uncertainty base either of your level of detection or based on the grades you put for every input.

You know, if you have whatever, how many

grades you have, four or five, four -- like you want three.

MR. KAIZER: It varies for each one, yes.

MEMBER DIMITRIJEVIC: Let's say that all four of your uncertainty grades will be these sort of -- you know, if you have a different mix, the importance of the different things.

But, basically, like in the PRA, with the PRA we often say, even we start using numbers now all the time. The numbers are not so important, and actually, where you can see where your contribution comes from, the difference, you know.

MR. KAIZER: I didn't get back to it, but in the Predictive Capability Maturity Model, which they started at Sandia, and it kind of failed initially, when they started using it later, that conclusion was this is helpful if we ignore the numbers, but we see which ones are the major contributors.

MEMBER DIMITRIJEVIC: Yes.

MR. KAIZER: In this one, I don't think it's refined enough because it tries to give you the quantitative answer that PRA does, but, to me, this is just it's a logical map like PRA is. It's a mental map. You can think about it. You put it down. It

makes more sense --

MEMBER DIMITRIJEVIC: Your process of development is equally important as that. We forget now because we are 40 years in development and everybody forgets where the actual module came from.

MR. KAIZER: Yes.

MEMBER MARCH-LEUBA: Essentially, we're so used to thinking about uncertainties, but you have to remember that this process gives you the quality of your decision. You want the uncertainty and the quality because the correlation -- at the end, you have data and you have your correlation. You fit it, and you know what the error in the uncertainty and the correlation is.

What this more allows you to define is the quality of that.

MR. KAIZER: Yes.

MEMBER MARCH-LEUBA: And looking for uncertainty in her quality, I don't know. I mean, I think we're overdoing it then.

MR. KAIZER: It would be fun to do it. How would you do an uncertainty?

MEMBER DIMITRIJEVIC: Well, how would you define, I mean, how would you define quality of the software?

MEMBER MARCH-LEUBA: But, at the end of the process, he says this is credible or this is not credible.

MR. KAIZER: Yes.

MEMBER MARCH-LEUBA: So, what you say is it's credible plus or minus --

MEMBER DIMITRIJEVIC: But the problem, his design is obviously -- Because his purpose is to calculate your what, critical heat flux? Gives you a number which can be blah, blah, blah or it can be blah, blah, blah two. Which one is the better? See, that's not credible. That doesn't like to do quality. It just gives you chances to say it's good enough.

MEMBER BLEY: Well, and that's what the ordinal scales do.

MEMBER DIMITRIJEVIC: Yes.

MEMBER BLEY: Once you've exercised them, you get to a point and you say this is acceptable. But it's really a good enough kind of thing.

MR. KAIZER: Yes, it's binary. I mean, to me, every decision by every decisionmaker is ultimately binary. Yes, we're going forward; no, we're not. And so, you just try to come up with this framework. Yes, that's how I defined credibility or I tried to, which is, yes, it's credible, we're going

to go forward; no, it's not credible; stop, we're not going to go forward. And I think you need a way to reach that from the decisionmaker's --

MEMBER MARCH-LEUBA: You can tell the vendor it's not credible because it failed G12.

MR. KAIZER: Yes, yes.

MEMBER BLEY: Well, going back to your analogy to the PRA, which there is some, but I don't know how many times you've done this, but it hasn't been all that many. Ten years from now when you've had a lot of experience, there may be apparent ways to make this more quantitative and clear. But, right now, it seems to me it is better than anything I've seen to get a good review.

MEMBER DIMITRIJEVIC: Well, was it the case when Jose jumped because there was two totally different critical heat flux results in something we reviewed?

MEMBER BLEY: Yes, yes.

MEMBER DIMITRIJEVIC: Remember when you got upset? Okay, so --

MEMBER MARCH-LEUBA: I didn't get upset. I told them something was wrong.

(Laughter.)

MEMBER DIMITRIJEVIC: Yes, but --

MEMBER BLEY: They'll figure it out.

(Laughter.)

MEMBER DIMITRIJEVIC: Would those both pass this?

MEMBER BLEY: They might have.

MEMBER MARCH-LEUBA: No, they were using two different correlations for two different calculations.

MEMBER BLEY: Yes.

MEMBER MARCH-LEUBA: And now, we're reviewing two Topical Reports. Well, you haven't met the V&V yet.

MEMBER BLEY: Either of those correlations might have passed this process.

MEMBER DIMITRIJEVIC: Yes.

MEMBER BLEY: But they're different for particular reasons. But, then, you learn some more and you --

MEMBER MARCH-LEUBA: It's not proprietary. There were two different correlations. One was a critical heat flux and the other was a critical power issue. And they were giving you the numbers.

CHAIRMAN RICCARDELLA: I've seen processes where people are going to run a lot of tests. And say you're going to run 500 tests, and they take 400 of

those tests and they train their correlation on those 400. And then, they test them on another group. Is some of that built into this?

MR. KAIZER: Yes. So, the training validation split and the way we've actually -- I don't give the thing back here, let's see, in mathematical. It's one of the validations. We tell you, okay, how much data are you using for training, and we give it a percentage. The highest credibility is that you're using zero percent of your data for training. The lowest credibility is you're using 100 percent of your data for training.

CHAIRMAN RICCARDELLA: Okay.

MR. KAIZER: And then, validation, we ask the same question and we reverse it. And there's even another, I won't say it's a pseudo-requirement, but because, as a regulator, I don't care how well your correlation predicts data that it already saw; I care how well your correlation predicts data that it hasn't seen yet. We pretty much say you should not be developing your uncertainty on the data that was used to train your correlation. You should only be developing your uncertainty on the data that was used to validate.

MEMBER MARCH-LEUBA: But it also forces

you to question the quality of the experimental data.

CHAIRMAN RICCARDELLA: Yes.

MEMBER MARCH-LEUBA: For example, in the red dot fuel, the rollout is going to go like this letter.

CHAIRMAN RICCARDELLA: Yes.

MEMBER MARCH-LEUBA: We can develop a polynomial that fits it perfectly.

CHAIRMAN RICCARDELLA: Sure.

MEMBER MARCH-LEUBA: But maybe the guys that took this, they didn't know how much copper was in --

CHAIRMAN RICCARDELLA: That data was valid, but there was an ASTM committee that scrubbed that data.

MEMBER MARCH-LEUBA: Yes, I know, but --

CHAIRMAN RICCARDELLA: I don't know if they used all of your processes, but, I mean, it wasn't just --

MEMBER MARCH-LEUBA: Just the fact they used 400 points for the data doesn't mean the 400 points were good.

CHAIRMAN RICCARDELLA: Yes.

MEMBER MARCH-LEUBA: If you didn't know what the chemistry of your sample was, the data is

useless. And this process forces you to check the experimental evidence; does it cover the intended use?

CHAIRMAN RICCARDELLA: Yes.

MEMBER DIMITRIJEVIC: You don't think that the time traveling guide developed the correlationship of that data because he had too many variables. It's not like two-dimensional. It doesn't really fit all the time.

MEMBER MARCH-LEUBA: I think it's a novel approach. As we told them, once you see a wheel, you say, "Yes!" But the first man that came up with the wheels, they said, "Oh, look at this! That was good."

(Laughter.)

CHAIRMAN RICCARDELLA: So, could we develop this process to help us pick stocks? Then, maybe we wouldn't have to work that much.

(Laughter.)

MEMBER REMPE: We're still on the record. I think we ought to thank Jose for bringing it to our attention instead of worrying about your finances.

(Laughter.)

MR. KAIZER: Actually, the person who's got the most developed one of these frameworks that I've seen is actually the diamond industry because they have the four Cs: caret, cut, clarity, and

color. And you can grab their diamond chart and it's set up like a framework, and they actually have extremely defined levels of what's in each level. And there is even -- and I was talking to Tomasz Kozlowski from the University of Illinois. He said that there is a machine-learning database that gives you the value of like something like 150,000 diamonds and it tells you the value in their charts and it tells you the price of the diamond. So, the idea is, can you come up with a machine-learning technique to determine prices of diamonds better than anyone else?

So, people have used something like this to come up with something monetary. Although if I could come up with something with stocks, I'm not sure I would -- I'll say I probably still would be here. I like this job.

(Laughter.)

MEMBER DIMITRIJEVIC: You know, why cannot the review this morning as a part of our QA instead of these NUREGs we selected?

MEMBER REMPE: Because the Office of Research selects, provides us a list, and we must pick something from it. And again, that's another topic. But, as you know, that may not be continuing in outyears anyhow, but that's why it was not on --

MEMBER DIMITRIJEVIC: Yes, but we didn't finish reviewing the --

MEMBER REMPE: But we have to pick something from the list that Ray Furstenau provided.

MEMBER MARCH-LEUBA: It will be issued next year. We can hint that we would like to see it again.

MEMBER BLEY: If we want to write a report on this, we could do it.

MEMBER REMPE: We are doing a Letter Report on this. Jose has a draft Letter on it. That's another reason, too. So, we're writing a letter on it.

MEMBER BLEY: So, thank you, guys. It was a little more fun than what we usually do.

MEMBER REMPE: That's why we should thank Jose for bringing it.

MEMBER MARCH-LEUBA: As another topic, I would like to poll the members if we would like to write a letter on this NUREG to the Commission, because I do have one ready --

MEMBER REMPE: Oh, I thought we were doing it.

MEMBER MARCH-LEUBA: -- if we want to do it.

MEMBER REMPE: We'll see how the letter is.

MEMBER KIRCHNER: But we did give favorable mention to this framework in the letter. What was it? Was it NuScale or was it --

MEMBER MARCH-LEUBA: 1.99

MEMBER KIRCHNER: -- or APR1400? Who sees that correlation --

MEMBER MARCH-LEUBA: We made some decision in 1.99 orally. Nothing that I --

MEMBER KIRCHNER: Anyway, we have a letter that references this, but at that point it was part of --

MEMBER MARCH-LEUBA: Oh, that's D5.

MEMBER REMPE: Yes.

MEMBER PETTI: But I think --

MEMBER BLEY: That wouldn't shine the same kind of light on it.

MEMBER PETTI: Yes, I think a separate letter where we particularly talk about the applications beyond the limited application here.

MEMBER REMPE: We've got a draft.

MEMBER PETTI: Right. So, I don't have a problem with that.

MEMBER MARCH-LEUBA: Okay, I'll take a

unanimous consent.

MR. LUKES: Bob Lukes. Is this one (referring to microphone)?

CHAIRMAN RICCARDELLA: Yes.

MR. LUKES: Great. Bob Lukes. I'm the Chief of the Nuclear Methods and Fuels Branch. I'm Chief of Josh and was Reed until he abandoned me.

(Laughter.)

So, three years ago I took this job, and I think the Nuclear Methods is probably the most technical branch in the NRC, aside from our research sisters. And Josh, three years ago, dropped the CHF on my desk, when I first got the job. And I'm like, okay, I've got to learn this. So, I pulled down this thing called NUREG-0800, the Standard Review Plan, to look at it, and it says nothing.

(Laughter.)

So, I called Josh and I'm like, "How did you do this?" Right? "There's no way you did it from this." And he drops a verification and validation textbook on my desk.

(Laughter.)

And I'm like, "What is this?" He tells me, "Don't worry. I've got it covered."

MR. KAIZER: It's this one, if anybody

wants it.

(Laughter.)

MR. LUKES: Yes, that's the one. And he gave it to me, actually. He gave me the copy.

Three years later, here we are. He independently without direction saw a need, saw a hole, wrote this new NUREG/KM. And I've done my best at throwing his praise above me, and I don't know if I've done a good job. So, I just want to praise the ACRS for recognizing the importance of this and taking the time to let him come present.

Because, you know, as I entered the back third of my career, I realized that this is the legacy that we're going to have left here when everybody goes. And we're losing people more than we're getting new people. And we're losing knowledge. And everything he's done has been just knowledge management -- or what do we call it? -- tribal knowledge. Someone told him how to do it and nothing was ever written down. So now, we finally have something written down, and I just really want to give praise to the ACRS for recognizing that and seeing the importance of this.

MR. KAIZER: Thank you.

CHAIRMAN RICCARDELLA: Great. Thank you.

MEMBER DIMITRIJEVIC: That is for this co-creating, you know, for creating solutions.

MEMBER MARCH-LEUBA: Innovation.

MEMBER DIMITRIJEVIC: Innovation, exactly.

MEMBER MARCH-LEUBA: Maybe we just start in the letter.

MR. KAIZER: Okay. Thank you.

CHAIRMAN RICCARDELLA: Thank you.

MEMBER BLEY: We go to comments first.

MEMBER MARCH-LEUBA: Yes, yes.

MEMBER REMPE: Are there comments? Is there a phone line?

MEMBER MARCH-LEUBA: We already had some comments from the public. Any other comments from the public?

(No response.)

MEMBER REMPE: And the phone line?

MEMBER MARCH-LEUBA: We are going to open the phone line.

Anybody on the phone line?

(No response.)

MR. ANZALONE: We did go out for public comment and we did receive not an insignificant number of public comments from industry and academia. Most of them were --

MEMBER MARCH-LEUBA: Anybody on the phone line, can you identify yourself and provide us comments, if you have one?

(No response.)

Okay. Hearing none, we can close the line.

And please continue.

MR. ANZALONE: Oh, yes, I was just going to say most of them were primarily editorial in nature. I think we got a lot of comments agreeing with the overall approach, favorable comments.

MEMBER MARCH-LEUBA: It's good for the reviewers. It's good for the submittal. It's good for the public because we guarantee a certain level of predictiveness. The review, someone is told to have this much level.

CHAIRMAN RICCARDELLA: Okay. So, I think we'll go off the record now.

(Whereupon, the foregoing matter went off the record at 3:39 p.m.)

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Presentation to the ACRS

US-APWR Chapter 8

Electric Power

November 7, 2019

Mitsubishi Heavy Industries, Ltd.

MITSUBISHI HEAVY INDUSTRIES

Overview of Chapter 8: Electric Power

In accordance with RG 1.206 and the SRP, Chapter 8 consists of following subsections:

8.1 Introduction

8.2 Offsite Power System

8.3 Onsite Power Systems
- 8.3.1 AC Power Systems
- 8.3.2 DC Power System

8.4 Station Blackout

Offsite Power System (8.2)

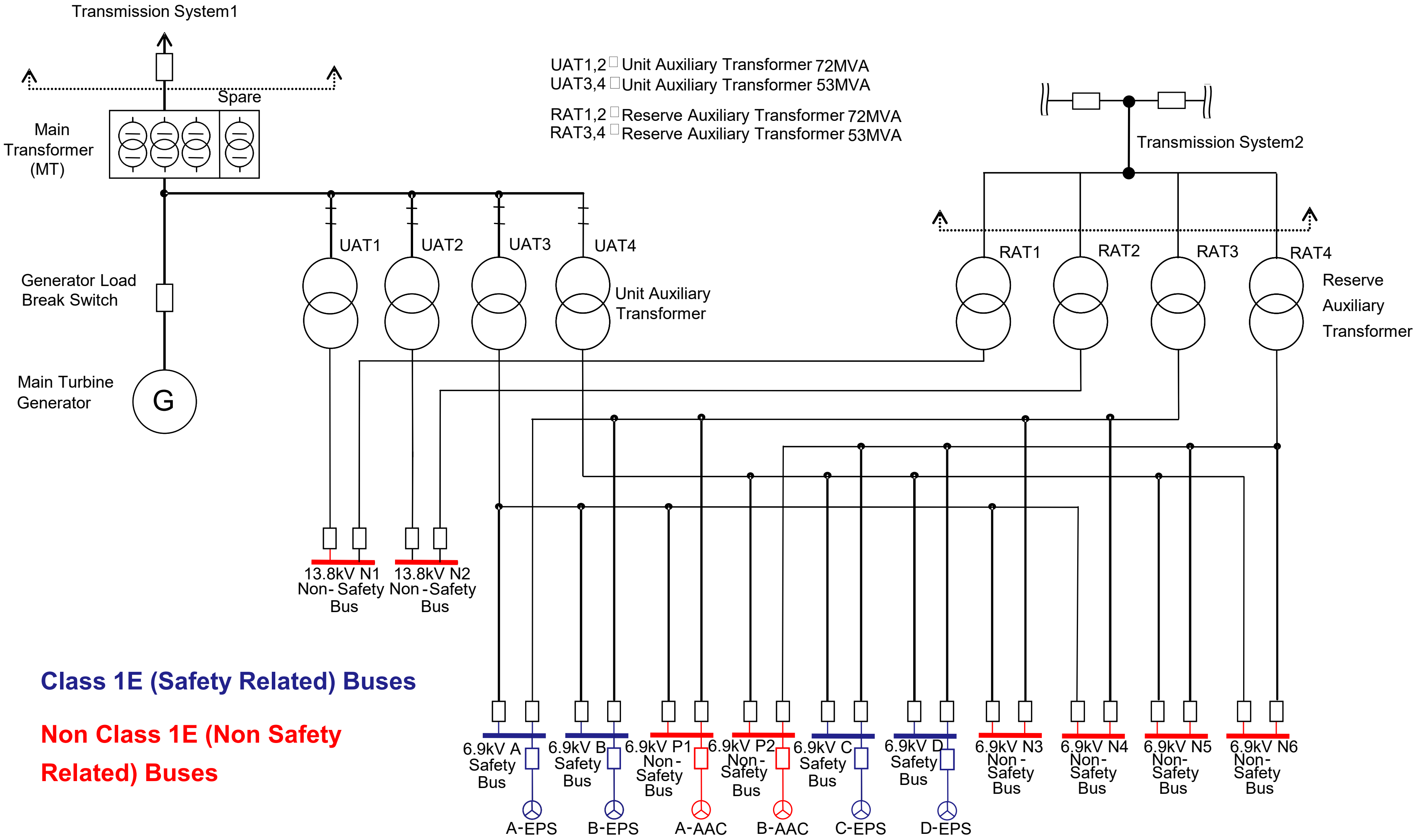
- **Design Features**
  - ✓ Two (2) sources of offsite power provide;
    1) Normal Preferred Power from Reserve Auxiliary Transformers (RAT)
    2) Alternate Preferred Power from Unit Auxiliary Transformers (UAT) through Main Transformer
  - ✓ The two (2) offsite power supply circuits are independent and physically separated.
  - ✓ Either offsite power supply circuit has the capacity for normal operations and Design Basis Events (DBE) to comply with the applicable GDC's.

Onsite Power Systems (8.3)

➢ Design Features

- ✓ Four train Class 1E AC electrical power systems
- ✓ Each train includes an independent Class 1E GTG as its emergency power source
- ✓ On-Line Maintenance with Single-Failure Criterion remains satisfied
- ✓ “Permanent” buses supplied from Alternate AC Power Source (AAC-GTG)
- ✓ Non-safety related loads are electrically separated from class 1E buses
- ✓ Required non-safety related loads are supplied from AAC during LOOP
- ✓ AACs provide power to all SBO required loads to bring and maintain the unit in safe-shutdown

Electrical Power System



Main One-Line Diagram

Class 1E Gas Turbine Generator (GTG) Specification/Rating

- **Gas Turbine Rating**
  - ✓ Continuous Rating: 4500 kW
  - ✓ Short time Rating : 4950 kW
- **Generator Rating**
  - ✓ Continuous Rating: 4500 kW / 5625 kVA
  - ✓ Power Factor: 0.8
  - ✓ 6900 Volt, 3 Phase, 60 hertz
- **Starting Time**
  - ✓ < 100 seconds

Class 1E GTG Testing Program

- **Regulatory Guide 1.9**
  - ✓ Application and Testing of Safety-related Diesel Generators in Nuclear Power Plants
- **IEEE 387**
  - ✓ IEEE Standard Criteria for Diesel Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations.
- **ISG-21 (Draft)**
  - ✓ Interim Staff Guidance On the Review of Nuclear Power Plant Designs using a Gas Turbine Driven Standby Emergency Alternating Current Power System
- **MHI Technical Report (Qualification Test Plan and Initial Type Test Result)**
  - ✓ Qualification and Test Plan for Class 1E Gas Turbine Generator System: MUAP-07024
  - ✓ Initial Type Test Result of Class 1E Gas Turbine Generator System: MUAP-10023

Class 1E GTG Initial Type Tests

- **Load Capability Test**
  - ✓ IEEE 387 6.2.1
  - ✓ To demonstrate the capability to carry rated load
- **Start and Load Acceptance Test**
  - ✓ IEEE 387 6.2.2
  - ✓ To establish the capability to start and accept load within the required time period
  - ✓ 150 Start Tests
- **Margin Test**
  - ✓ IEEE 387 6.2.3
  - ✓ To demonstrate the capability to carry the most severe load step + 10%

Station Blackout (8.4)

- **Basic Concept for Coping with SBO**
  - ✓ The AACs are available in the event of SBO, when all offsite power sources and EPSs are not available to bring the unit to a safe shutdown condition and maintain that status

- **Design Basis**
  - ✓ Diversified AACs to minimize the potential for common cause failures between AAC and EPS system
  - ✓ The non-class 1E AAC is a packaged gas turbine-generator connected to a 6.9kV AC “Permanent” bus
  - ✓ AAC can be aligned to any of the 4 class 1E buses in response to an SBO
  - ✓ AAC supplies safe shutdown loads during the SBO coping period (8 hours)

Open Phase Condition

NRC Bulletin 2012-01, "Design Vulnerability in Electric Power system," addressed the loss of one of the three phases of offsite power (single-phase open circuit condition) at Byron Station

MHI Response to Provide Protection against OPC (Open Phase Condition)

(1) Detection and Protection Method

(2) Single Failure Criteria

(3) COL and ITAAC

Open Phase Condition

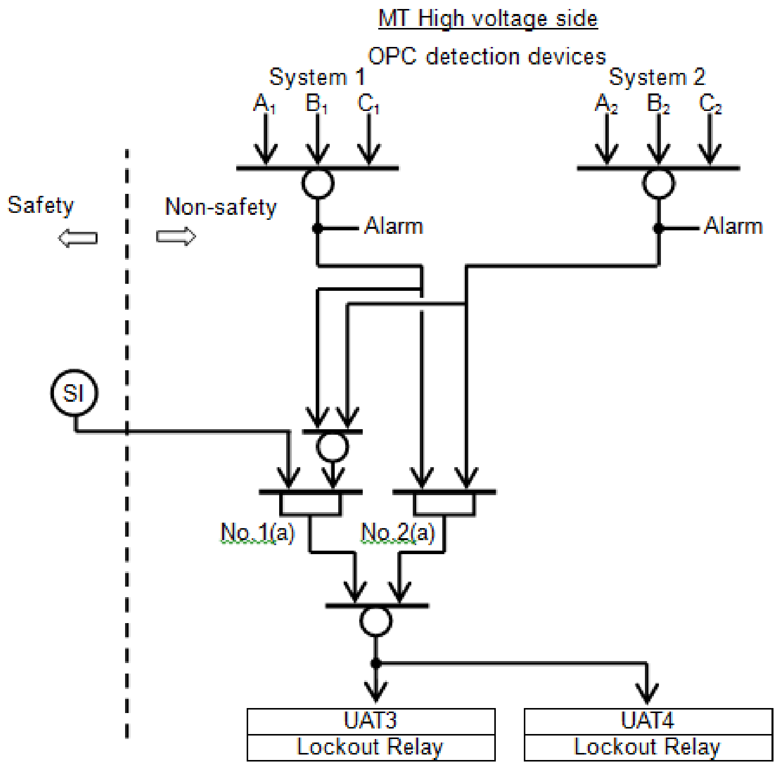
- **MHI Response**

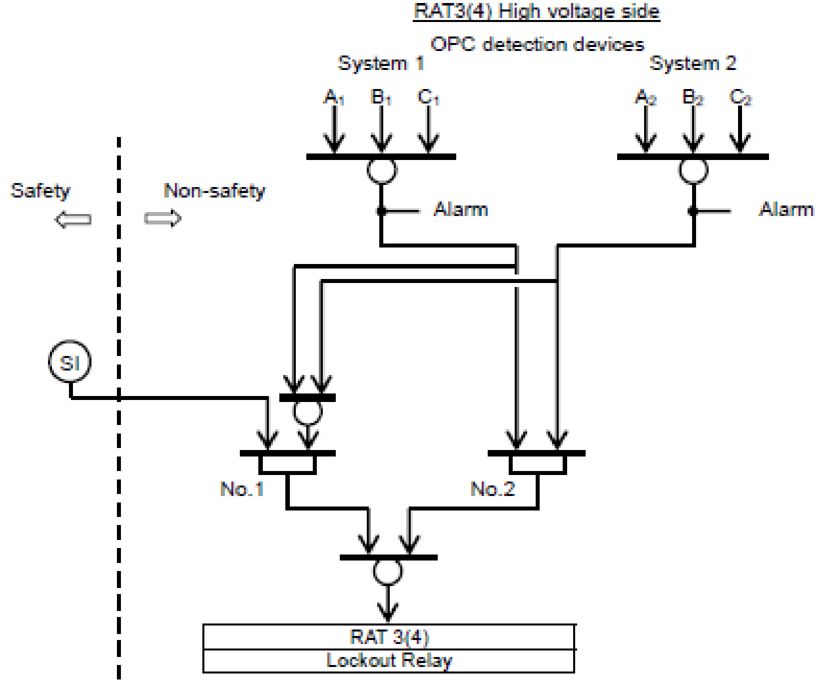
  (1) Detection and Protection Method

  OPC detection systems are provided on the high voltage side MT and RAT.

  (2) Single Failure Criteria

  OPC detection system has redundancy.





Open Phase Condition

(3) COL Item and ITAAC

- ✓COL items on detail designs and surveillance requirement were added in DCD section 8.2.

COL 8.2(12)	~~Deleted~~ The COL applicant is to determine the specific type of the OPC detection devices which properly address and meet the requirements of B.1. & B.2. of BTP 8-9, taking into account the site-specific design configuration, installation condition, (field) performance testing and qualification status, and operation experiences of the OPC Detection and Protection system. The COL applicant is also to provide the detailed design of the OPC Detection and Protection system for the COL applicant site. The COL applicant is to perform a field simulation on the site-specific design of the offsite power system to ensure that the settings of the OPC Detection and Protection system are adequate and appropriate for the COL applicant site.
COL 8.2(13)	The COL Applicant is to provide surveillance requirements for the device(s) used to detect open phase condition on the high voltage side of the RATs and MT, with or without grounding.

- ✓One ITTAC was added in Tier 1 of DCD.

Table 2.6.1-3 AC Electric Power Systems Inspections, Tests, Analyses, and Acceptance Criteria (Sheet 8 of 8)

Design Commitment	Inspection, Test, Analyses	Acceptance Criteria
28 The Class 1E equipment is protected from open phase conditions with monitoring, detecting and alarming in the main control room.	28.i Analysis will be performed verify the Class 1E equipment is protected from open phase condition.	28.i A report exists and concludes that the Class 1 E equipment is protected from open phase condition by open phase protection system.
	28.ii Inspection and test will be performed to verify the as-built protection system bounds the result of analysis for Class 1E equipment protection from open phase condition and to verify that open phase condition will be monitored, detected and alarmed in the main control room.	28.ii The as-build protection system bounds the result of analysis for Class 1E equipment protection from open phase condition. The as-built detection system design monitors, detects and alarms in the main control room.

Supporting Documentation

Technical Reports

#	No.	Rev.	Document Title	Issue Date	Submittal Date	MHI Ref.
1	MUAP-09023	1	Onsite AC Power System Calculation	Aug. 2013	Sep. 3, 2013	UAP-HF-13221
2	MUAP-07024	3	Qualification and Test Plan of Class 1E Gas Turbine Generator System	Sep. 2012	Sep. 28, 2012	UAP-HF-12270
3	MUAP-10023	7	Initial Type Test Result of Class 1E Gas Turbine Generator System	Dec. 2013	Dec. 18, 2013	UAP-HF-13311

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Presentation to ACRS

Chapter 18

November 7, 2019

Mitsubishi Heavy Industries, Ltd.

Contents

1. Supporting Documentation
2. US-APWR HFE Program Management Plan
3. US-Basic HSI
4. Summary

Supporting Documentation

Technical Reports

#	No.	Rev.	Document Title	Issue Date	Submittal Date	MHI Letter #
1	MUAP-09019	5	Human Factors Engineering Program Management Plan	Aug. 2014	Aug. 22, 2014	UAP-HF-14047
2	MUAP-13005	1	Operating Experience Review Implementation Plan	May 2014	Jun. 4, 2014	UAP-HF-14042
3	MUAP-13007	1	Functional Requirements Analysis and Function Allocation Implementation Plan	May 2014	Jun. 4, 2014	UAP-HF-14042
4	MUAP-13009	1	Task Analysis Implementation Plan	May 2014	Jun. 4, 2014	UAP-HF-14042
5	MUAP-10008	4	Staffing and Qualifications Implementation Plan	May 2014	Jun. 4, 2014	UAP-HF-14042
6	MUAP-13014	1	Human Reliability Analysis Implementation Plan	May 2014	Jun. 4, 2014	UAP-HF-14042
7	MUAP-10009	4	Human-System Interface Design Implementation Plan	May 2014	Jun. 4, 2014	UAP-HF-14042
8	MUAP-10012	4	Human Factors Verification and Validation Implementation Plan	May 2014	Jun. 4, 2014	UAP-HF-14042
9	MUAP-10013	4	Design Implementation Implementation Plan	May 2014	Jun. 4, 2014	UAP-HF-14042

Supporting Documentation

Topical Report

#	No.	Rev.	Document Title	Issue Date	Submittal Date	MHI Letter #
10	MUAP-07007	6	Human-System Interface System Description	May 2014	Jun. 4, 2014	UAP-HF-14042

Audited Documents

#	No.	Rev.	Document Title	Issue Date	Audit Date
11	JEJC-1763-1001	2	HSI Design Style Guide	May 2008	May 26th and July 12th, 2010
12	7DS-UAP-20140012	0	Operating Experience Review Results	Aug 2014	August 22th, 2014

2. US-APWR HFE Program Management Plan

2. US-APWR HFE PMP

- ✓ The US-APWR HFE program implementation plan was developed in accordance with NUREG-0711, Revision 2, “Human Factors Engineering Program Review Model,” issued February 2004.

- ✓ The scope of the HFE PMP includes:
  - HFE design team and organization, roles and responsibilities
  - HFE process and procedures
  - HFE issues tracking (HED process)
  - HFE technical program
  - Combined license (COL) information

- ✓ For HFE activities completed within the scope of the US-APWR design, the program element methodology is described within an implementation plan (IP) and the element is documented in a results summary report (ReSR) as per the IP.

2. US-APWR HFE PMP

- ✓ The US-APWR HSIS is based on application of the US-Basic HSIS, which establishes the generic monitoring, alarm, control, and computerized procedure technologies to be employed in the Main Control Room (MCR) for all plant systems.

- ✓ The generic HSI technologies of the US-Basic HSIS are combined with the specific HSI inventory needed for the US-APWR plant design to create the US-APWR HSIS.

- ✓ The development process for a US-APWR site-specific HSIS confirms or changes the HSI inventory to reflect a site-specific plant.

- ✓ A fundamental design assumption and constraint of the US-Basic HSIS that also applies to the US-APWR HSIS is that the plant can be operated with minimum operation staff, one RO and one SRO in the MCR during postulated plant operating modes.

3. US-Basic HSI

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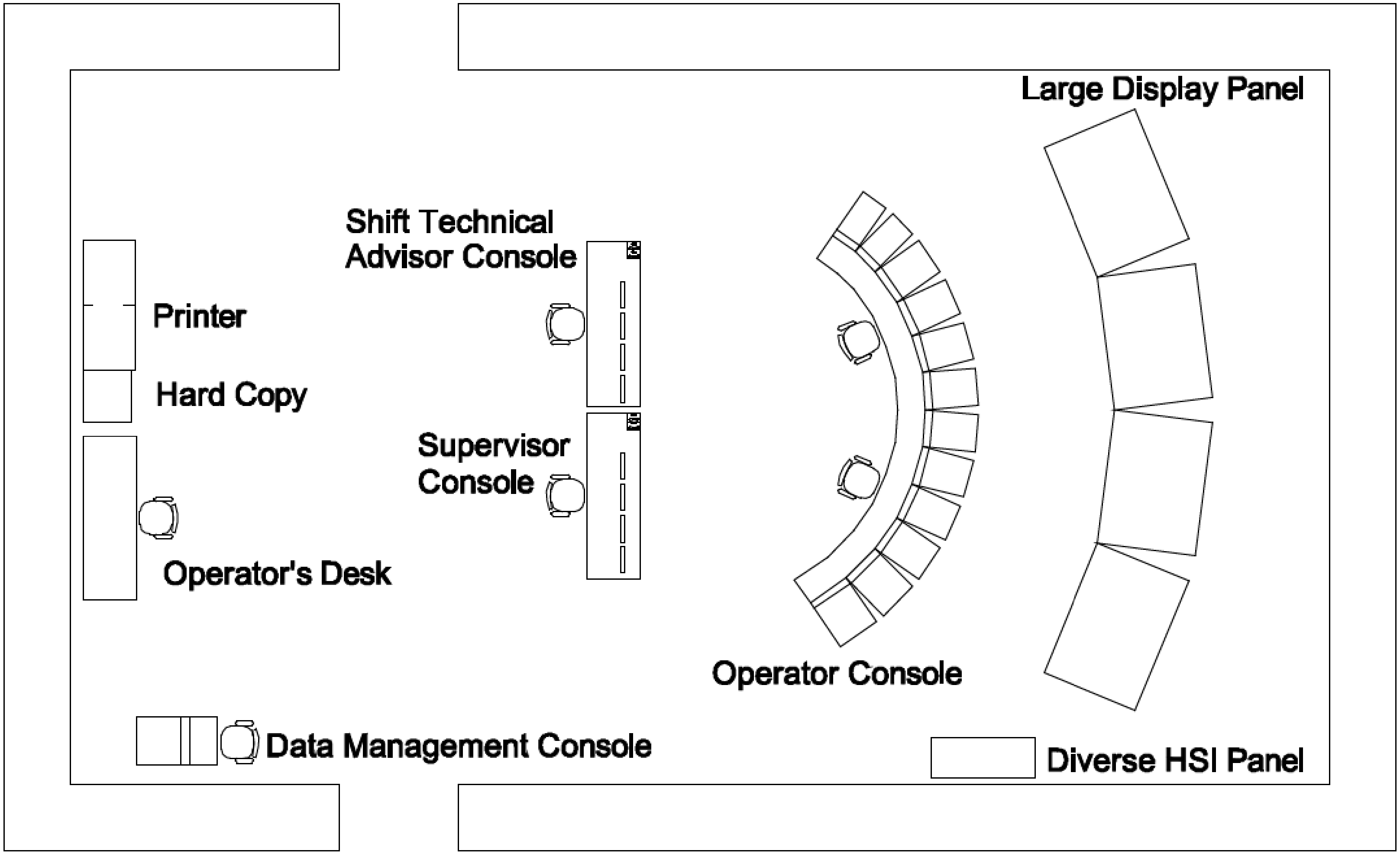
US-Basic HSI features and functions

- Submitted as a topical report, MUAP-07007
- MHI used the foundational elements of the Japanese-Basic HSIS as a starting point to create the US-Basic HSIS, applying combinations of design review, redesign, and design validation through a phased implementation
- Appendix A contains information about the Japanese-Basic HSIS & development history
  - Developed Japanese-Basic HSIS with Japanese utilities from 1987 to 2003 with guidance from NUREG-0711 and NUREG-0700
  - Japanese operators were involved in conducting V&V
  - Introduced Japanese HSIS to Japanese latest plant design and MCR modernization
  - No performance issues identified

US-Basic HSI

- Operating crew composition
  - The normal MCR staffing consists of one RO and one SRO
  - The normal MCR staff is supplemented by one additional SRO and one additional RO that will be at the plant to accommodate unexpected conditions
  - While the HSIS is designed to support the minimum MCR staffing described above, the space and layout of the MCR are designed to accommodate the foreseen maximum number of operating and temporary staff

MCR personnel allocation



US-Basic HSIS simulator

VDU application	Main purpose
operational VDU	To execute all of the plant control and monitoring functions, including control of the safety systems.
safety VDU	To execute the safety-related control and monitoring functions as a backup for the Operational VDU. It can control operation signals from the Operational VDU.
alarm VDU	To acknowledge and display individual alarms using prioritization color codes. Alarm VDU also provides the alarm confirmation/non-confirmation information to the operator.
operating procedure VDU	To provide computer-based operation procedure displays near the operational VDU and the alarm VDU in order to facilitate and simplify the performance of operation procedure.

4. Summary

Summary

- MHI has developed its US-Basic HSIS and used the US-Basic HSIS for the US-APWR HFE program application.

- US-APWR DCD has one COL item (in HPM) and two ITAAC items.

- When HFE programs have been implemented, Results Summary Reports will be submitted by MHI to NRC for NRC review.

ITAAC

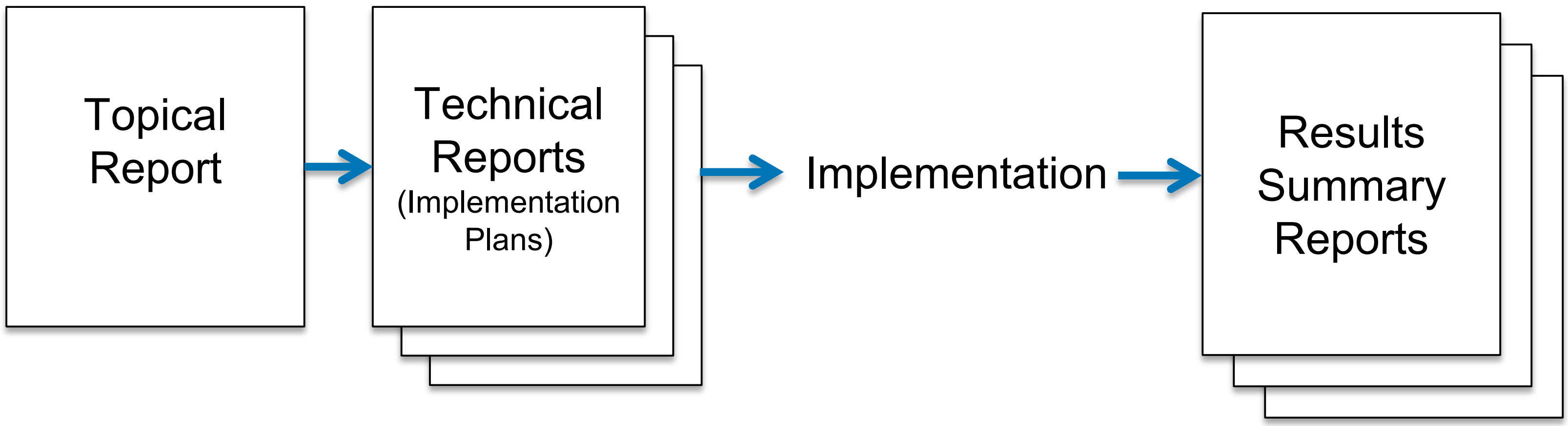
These ITAAC items will confirm the proper implementation of the program

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1. The Control Room design incorporates human factors engineering principles that minimize the potential for operator error.	1. An Integrated System Validation (ISV) test will be performed in accordance with the Human Factors Verification and Validation implementation Plan.	1. All pass/fail criteria associated with each test scenario are passed either on initial performance of the scenarios or following remediation of failures.
2. The as-built Control Room Human-System Interface is consistent with the final validated design specifications.	2. An inspection of the as-built Control Room Human-System Interfaces will be performed.	2. The as-built Control Room Human-System Interface conforms to the validated design with no configuration deviations.

(DCD Tier 1 Section 2.9 Table 2.9-1, DCD Rev.4 Markups, UAP-HF-14042)

Summary of Progam Structure

US-Basic HSI | Plant Specific Design Application



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Presentation to the ACRS

Topical Report MUAP-07001 Advanced Accumulator (ACC), Rev. 7

November 7, 2019

Mitsubishi Heavy Industries, LTD

US-APWR

MITSUBISHI HEAVY INDUSTRIES

Introduction

- The advanced accumulator (ACC) is an accumulator tank with a flow damper inside the tank that provides dual reactor injection flows with a highly reliable passive fluidic device as a part of the emergency core cooling system (ECCS) during a Loss-of-Coolant Accident (LOCA).
- Incorporation of the ACC into the LOCA mitigation strategy enables simplification of the ECCS configuration by eliminating the Low Head Safety Injection System (LHSIS) of a conventional Pressurized Water Reactor (PWR).
- The ACC topical report describes characteristics, operational principles, important design features, and testing programs that were conducted to verify the performance of the ACC and confirm the safety analysis model.

ACC Design Specification

Specification of the ACC

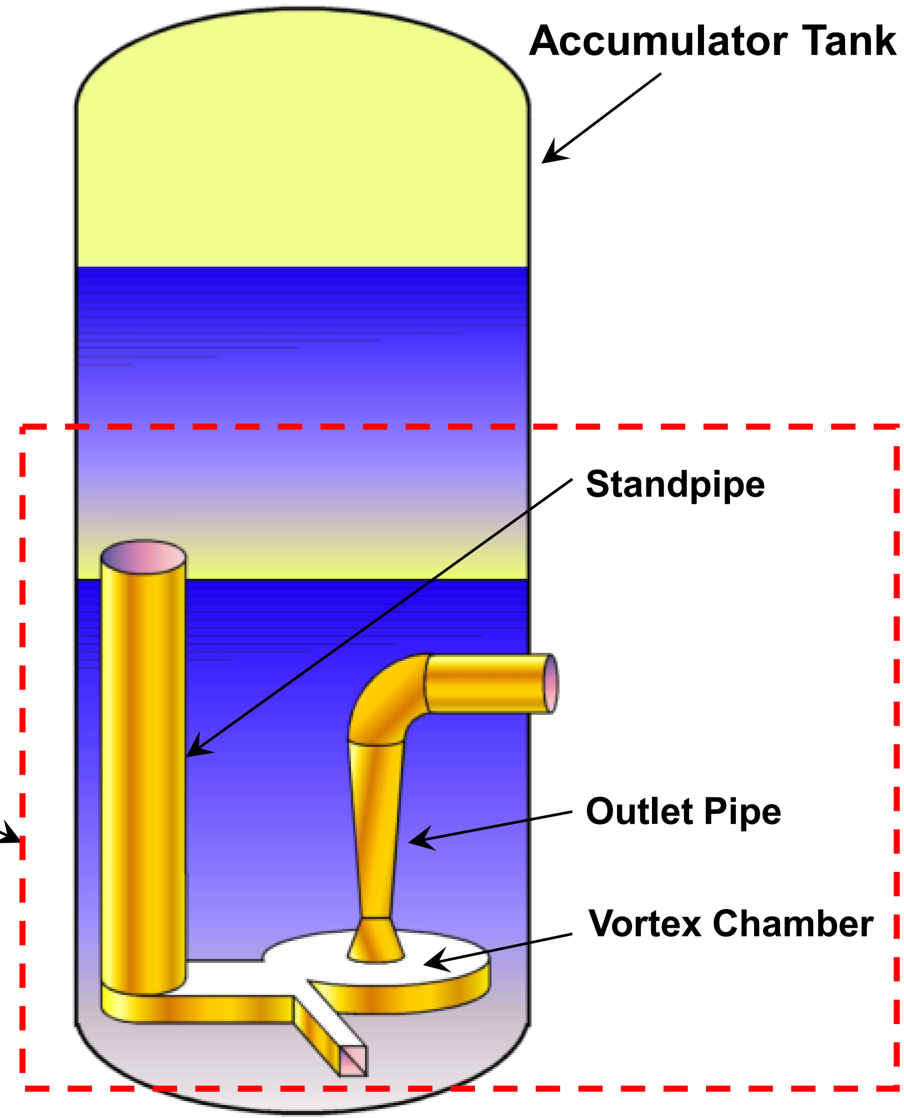
Type	Vertical cylindrical
Volume per tank	3,180 ft^3 (90 m^3)
Height	Approx. 30 ft (9.2 m)
Inner diameter	Approx. 12 ft (3.7 m)
Design pressure	700 psig (4.83 MPa[gage])
Design temperature	300 ^oF (149 ^oC)
Large flow injection volume per tank	1,342 ft^3 (38 m^3)
Small flow injection volume per tank	784 ft^3 (22.2 m^3)

MHI document US-APWR

Operational Principle (1/2)

➢ Structure of the ACC

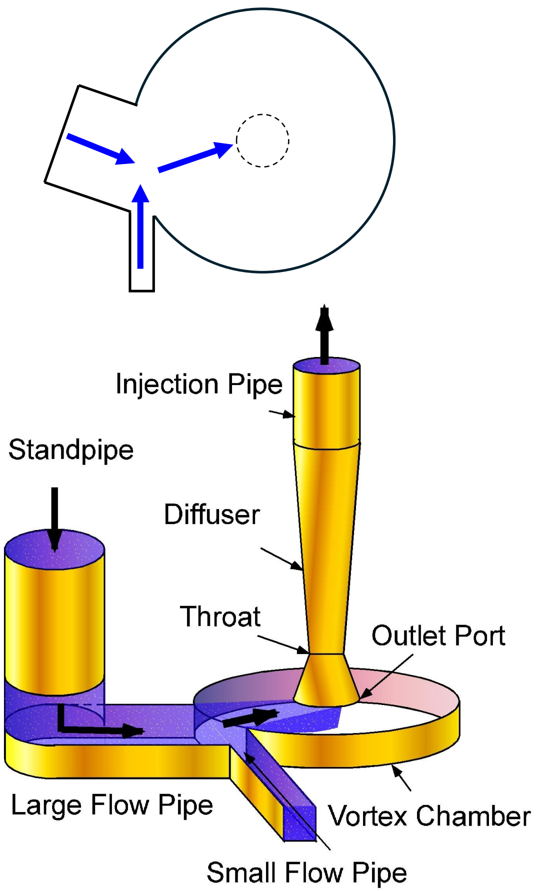
- ✓ Flow Damper is installed inside the tank
  - Vortex Chamber at bottom of Accumulator Tank
  - Standpipe connected to vortex chamber
  - Inlet port of standpipe at the middle of Accumulator Tank
  - Outlet pipe of vortex chamber connected to injection pipe

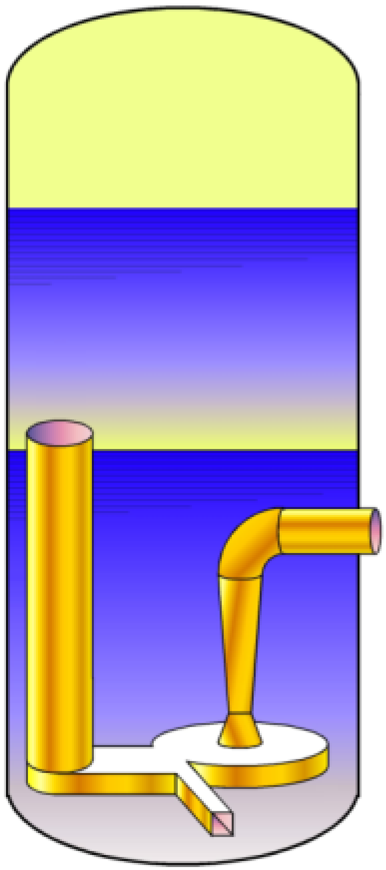


Operational Principle (2/2)

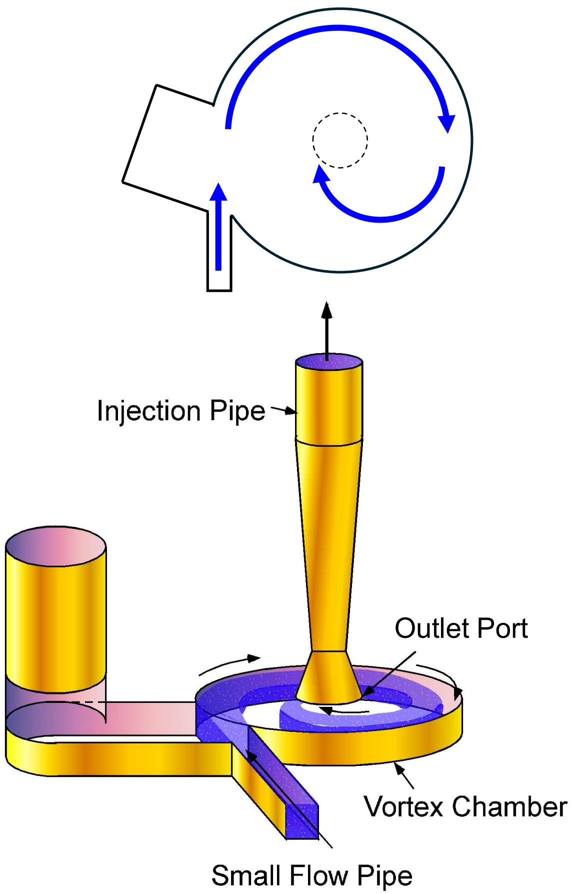
- Passive Flow Switching without need of Any Moving Parts

Large Flow Injection





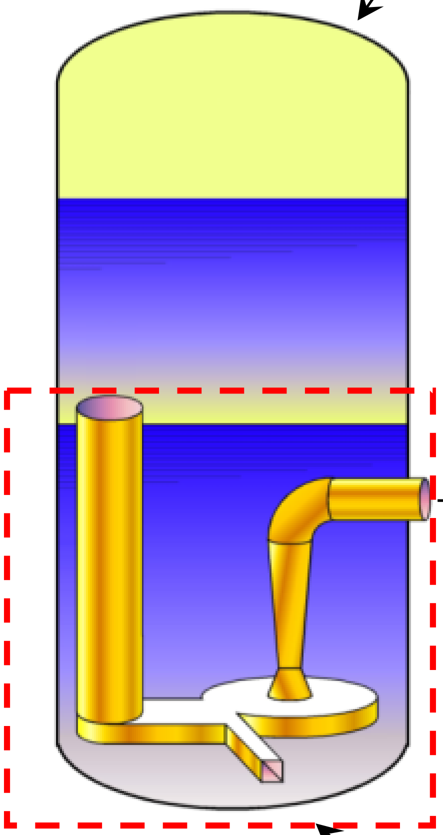
Small Flow Injection



MHI document US-APWR

Design Requirements

- **For Large Flow Injection Phase**
  - ✓ Required Performance
    - The lower plenum and the downcomer of the reactor vessel shall be filled with water as rapidly as possible during the refilling period.
  - ✓ Required Water Volume: ≥ 1307 ft^3 (37 m^3)



- **For Small Flow Injection Phase**
  - ✓ Required Performance
    - The downcomer shall be kept filled with water during the core reflooding period until SI pumps take over the injection
  - ✓ Required Water Volume: ≥ 724 ft^3 (20.5 m^3)

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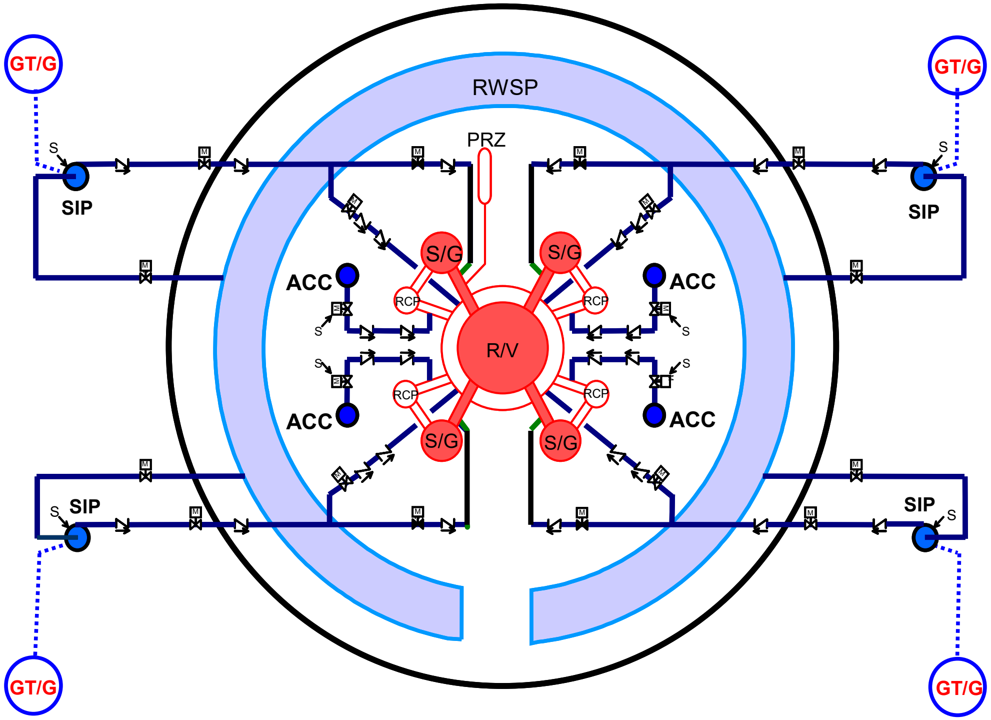
➢ Simplified ECCS configuration

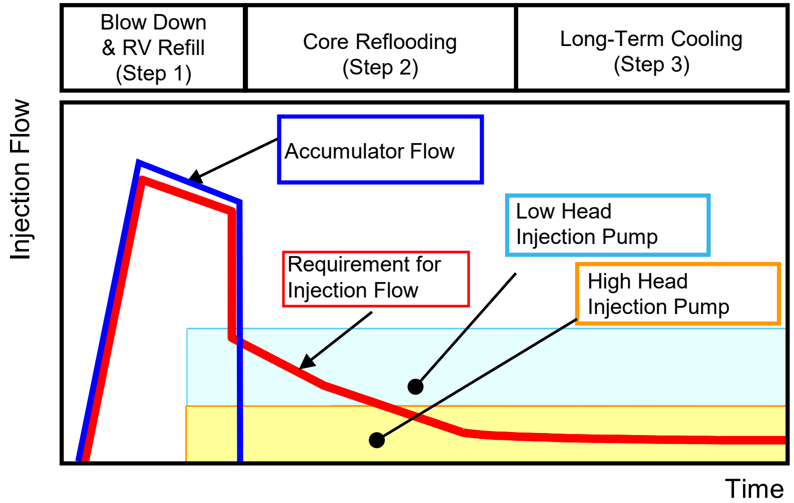
- ✓ Four ACCs connected to each Reactor Coolant System (RCS) cold leg.
- ✓ Four High Head Safety Injection Subsystems following accumulator injection.
- ✓ Low Head Safety Injection Subsystems are not installed.
- ✓ The ACC injects water longer than a conventional accumulator
  - Allowing more time for the Safety Injection Pumps (SIP) to start.
  - Allowing the use of gas turbine generators (GT/G) for the emergency power source, if needed.



RCP: Reactor Coolant Pump
R/V: Reactor Vessel
S/G: Steam Generator
PRZ: Pressurizer
RWSP: Refueling Water Storage Pit
ACC: Advanced Accumulator
SIP: Safety Injection Pump
GT/G : Gas Turbine Generator
S: Safety Injection Signal

- **ECCS with a Conventional Accumulator**

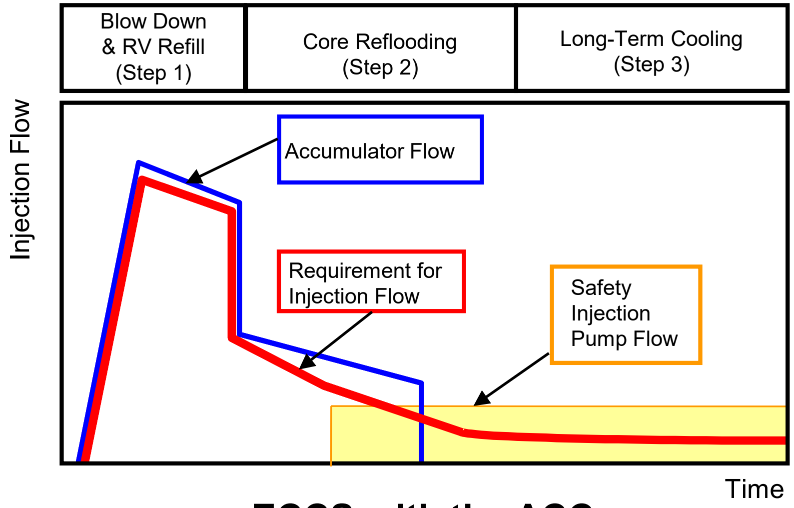
  ECCS function during a LOCA is assigned to three subsystems:
  - ✓ Accumulator System,
  - ✓ Low Head Safety Injection System (LHSIS),
  - ✓ High Head Safety Injection System (HHSIS).



ECCS with Conventional Accumulator

- **ECCS with the Advanced Accumulator (ACC)**

  The ACC automatically shifts its flow rate from large to small, allowing;
  - ✓ Elimination of the LHSIS and simplification of the ECCS.
  - ✓ More time before the safety injection pump and supporting emergency power are required.



ECCS with the ACC

Development Phase

- ✓ Confirmatory tests were performed using several scale models (1/8.4 scale, 1/3.5 scale, 1/5 scale).

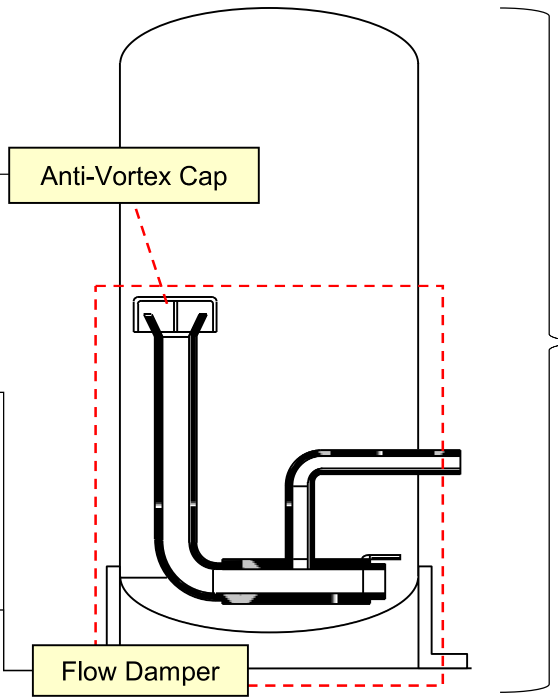
Design Verification Phase

- ✓ A qualification test was conducted using a full-scale test facility.

1/3.5 scale: To confirm effect of anti-vortex cap (prevention of vortex formation) at the end of large flow.

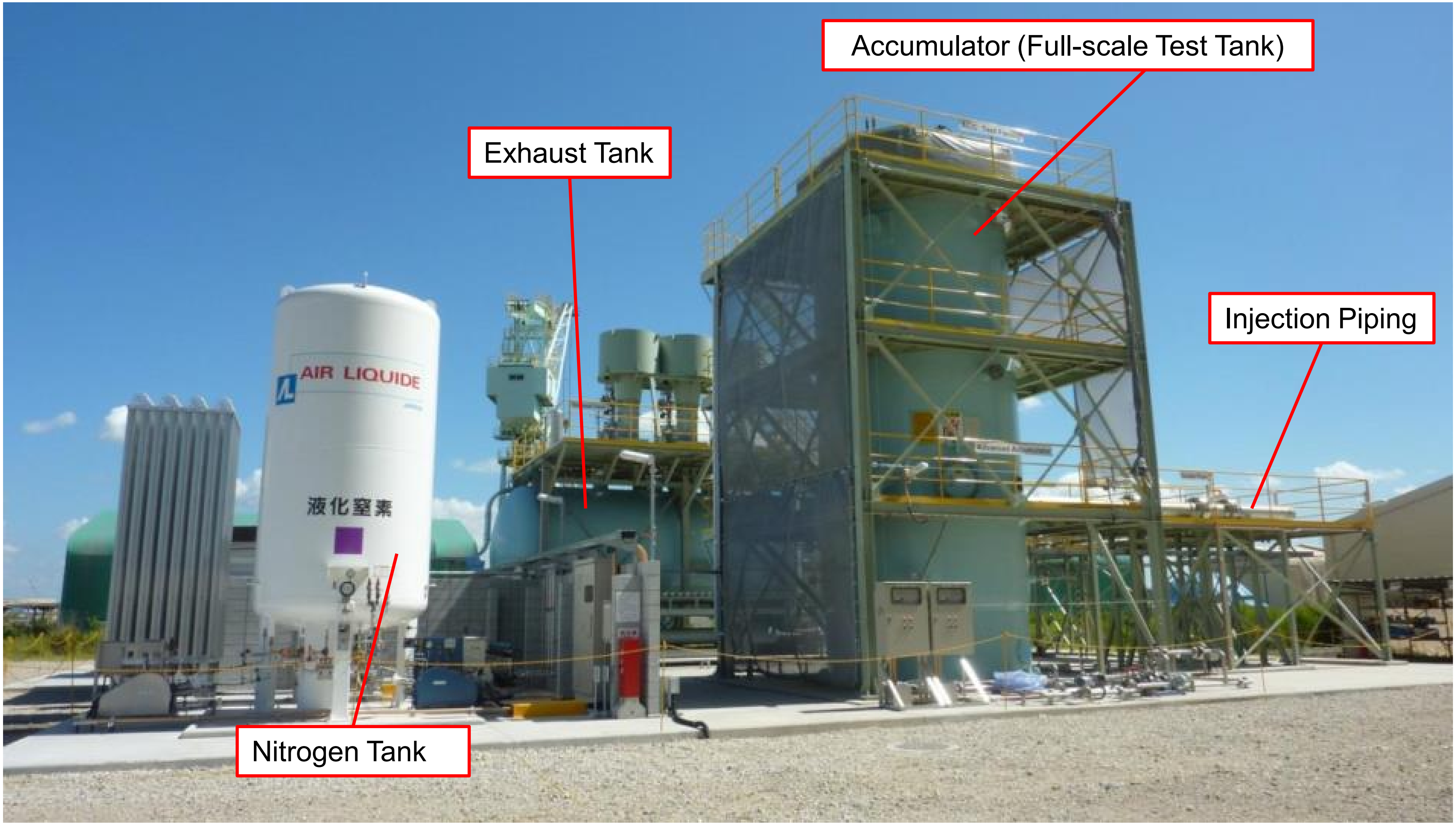
1/8.4 scale: To confirm principle of the flow damper during large and small flows.

1/5 scale: To confirm behavior of the flow damper with the condition closer to the actual operation.



1/1 scale: To verify design and performance of the ACC.

Full Scale Qualification Test



MHI document US-APWR

Summary and Conclusion

- The ACC design was verified by qualification testing using a full-scale test facility. The performance of the flow damper during large flow and small flow phases, and flow switching without any moving parts were verified.
- Empirical characteristic equations of flow rate coefficients have been developed from the qualification test results covering the range of the expected applicability under design basis LOCA conditions and are used in the ECCS analysis to confirm compliance with all US safety standards.
- As a conclusion, the ACC is applicable to the actual plant as a part of ECCS.

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Protecting People and the Environment

Presentation to the ACRS Full Committee

Mitsubishi Heavy Industries, Ltd.
US-APWR Design Certification Application Review

Safety Evaluation with No Open Items: Chapter 8

ELECTRIC POWER

November 7, 2019

Technical Topics
Section 8 – Electric Power

U.S.NRC
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Technical Topics

- US-APWR electric power system comprises of the following systems:
  - Offsite power system
  - Onsite AC power system, including 4 Class 1E trains each with a Class 1E Gas Turbine Generator (GTG), and Alternate AC source
  - Onsite DC Power System, including 4 trains of Class 1E 125Vdc

- Staff's review:
  - In the Phase 4 review the staff concluded that the DCD application, Chapter 8 met all applicable regulatory criteria.
  - In particular, the staff will discuss the closure of the following open items:
    - Open Phase Conditions (OPC)
    - GTG Reliability

Technical Topics
Section 8 – Electric Power

United States Nuclear Regulatory Commission
Protecting People and the Environment

Open Item #1: OPC

- Design criteria to address OPC includes:
  - Detection
  - Alarm
  - Response to a open phase conditions

- OPC protection features per BTP 8-9
  - COL Item 8.2(12) requires the COL applicant to identify the type of open phase detection and protection (OPDP) system.

Resolution of Open Item #1

- COL Item 8.2(12) will ensure that the COL applicant will determine an OPDP system that meets the guidance in BTP 8-9 including detection, alarm in the main control room (MCR), and protection features in that the Class 1E medium voltage buses will transfer to a power source without an open phase condition.

Technical Topics

Section 8 – Electric Power

Open Item #2: GTG Reliability

- MHI proposed the use of GTG as the Class 1E emergency power source.

- The challenges of this proposal included:
  - First of a kind application in the nuclear fleet, therefore there was no operating experience
  - No reliability data available

- In absence of operating experience and reliability data, the staff requested the applicant to perform type tests to ensure GTGs will perform their intended function and achieve their target reliability level.

Technical Topics
Section 8 – Electric Power

U.S.NRC
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Resolution of Open Item #2

- The GTGs have been qualified for Class 1E application using methodology and assumptions in Technical Reports MUAP 07024-P, “Qualification and Test Plan of Class 1E Gas Turbine Generator System.”

- The applicant documented the successful qualification of the Class 1E GTGs in Technical Reports MUAP-10023-P, “Initial Type Test Result of the Class 1E Gas Turbine Generator.”

- The result presented in Technical Report MUAP-10023-P states that to satisfy the starting reliability of 0.975 with 95 percent confidence, 150 start tests should be performed with no failures.
  - MHI performed 150 start and load acceptance tests of the GTGs.
  - The staff finds that these tests prove that the GTGs satisfy the reliability criterion of 0.975 with 95 percent confidence.

- In conclusion, the staff finds that the applicant’s approach to demonstrating Class 1E GTG reliability is adequate, considering compliance with GDC 17, conformance to RG 1.155, as well as successful qualification via type testing.

United States Nuclear Regulatory Commission

Protecting People and the Environment

Mitsubishi APWR Design Certification Review

SER Chapter 18

Human Factors Engineering Program

Presentation to the ACRS November 7, 2019

United States Nuclear Regulatory Commission
Protecting People and the Environment

Chapter 18 Review Team

Technical Staff

- Brian Green, Ph.D. NRR/DIRS/IOLB

Project Manager

- George Wunder, NRR/DONR/LB3

Conclusions

- The topical report describes an acceptable generic platform referred to as the US-Basic HSI.
- Implementation Plans provide confidence that iteration on the US-Basic HSI will be consistent with “state-of-the-art human factors principles” and applicable regulations.
- ITAAC will confirm that acceptable HFE practices are incorporated into the final design.
- There are no open or confirmatory items.

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Protecting People and the Environment

Presentation to the Full ACRS Committee

US-APWR Topical Report MUAP-07001, Advanced Accumulator (ACC), Rev.7

Safety Evaluation

November 7, 2019

Staff Review Team

- **Technical Staff**
  - **Getachew Tesfaye**

- **Project Manager**
  - **George Wunder – Lead PM**

Background

- Topical Report MUAP-07001, Revision 5, "The Advanced Accumulator”
  - Based on three small scale tests and full height 1/2 scale test with computational fluid dynamics (CFD) analyses for comparison with the fifth-scale and half-scale test results.
  - The ACRS concurred with the staff’s recommendation to approve the Rev 5 with an increased uncertainties that are used in loss of coolant accident (LOCA) analyses for the high-flow and low-flow injection regimes. The increased uncertainties account for the use of CFD analysis models to extend the half-scale test results to predict full-scale accumulator performance.
- Topical Report MUAP-07001, Revision 6
  - Based on three small scale tests and **full scale** test without CFD
  - Modified flow damper with a pressure equalizing pipe across the vortex chamber

Review Objectives

- Review compliance with GDC 35, “Emergency core cooling,” and 10 CFR 50.46, “Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors”
- Review the modified flow damper design and the reason behind the modification
- Review the adequacy of confirmatory scaled tests
- Review the adequacy the ACC full-scale qualification testing and the verification of the flow characteristics equations

Conclusion:

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- The staff reviewed US-APWR Topical Report MUAP-07001, Revision 7, "The Advanced Accumulator" (ML18178A267), along with the responses to the staff's requests for additional information. As a result of its review, the staff concludes:
  - that the characteristic equations developed from the full-scale test facility are comparable to the full height 1/2 scale test with CFD analyses to extend the half-scale test results to predict full-scale.
  - that the characteristic equations developed from the full-scale test facility are applicable to the full-scale accumulator with additional uncertainties and bias, which are described in the report.

MHI Generic List of Acronyms

ACC	Advanced Accumulator	PCT	Peak Clad Temperature
APWR	Advanced Pressurized Water Reactor	PRZ	Pressurizer
ECCS	Emergency Core Cooling System	PWR	Pressurized Water Reactor
GT/G	Gas Turbine Generator	RCS	Reactor Coolant System
GUM	Guide to the Expression of Uncertainty in Measurement	RCP	Reactor Coolant Pump
IEC	International Electro-technical Commission	R/V(RV)	Reactor Vessel
ISO	International Organization for Standardization	RWSP	Refueling Water Storage Pit
LOCA	Loss-of-Coolant Accident	S/G	Steam Generator
MHI	Mitsubishi Heavy Industries, Ltd	SI	Safety Injection
		SIP	Safety Injection Pump

Questions/Comments

Credibility Assessment Framework for Critical Heat Flux and Critical Power Models

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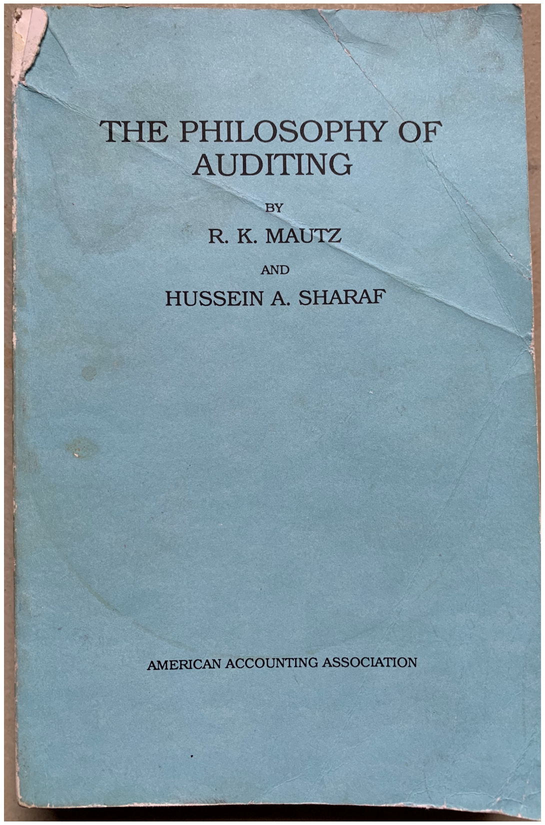
November 7, 2019

Motivation

- **Knowledge Management** (retirement of Tony Attard)
- Increase objectivity
- Increase efficiency



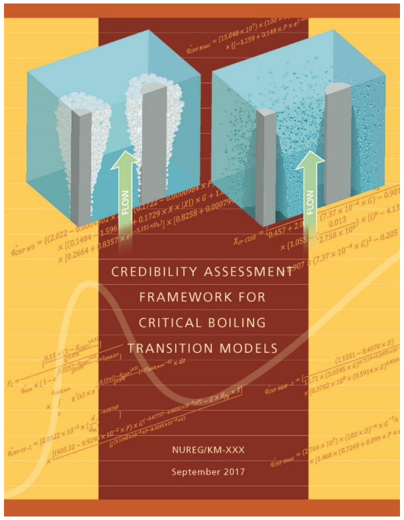
A textbook on how to perform a review.

NUREG/KM-0013 Outline

Chapter	Topic
1	Introduction to Credibility and Credibility Assessment Frameworks
2	Literature Review & Technical Background
3	Credibility Assessment Framework
4	Summary

Chapter 1

Introduction to Credibility and Credibility Assessment Frameworks



Credibility

Credibility - the determination that an object can be trusted for its intended purpose.

- Seems to appear just "off the main stage" of the VVUQ community
  - ASME V&V, VVUQ, V&V-10, V&V-20
  - Verification and Validation in Scientific Computing
  - Verification and Validation in Computational Science and Engineering
  - Fundamentals of Verification and Validation
  - Model Validation – Perspectives in Hydrological Sciences
  - NASA-STD-7009 – Standard for Models and Simulations
  - Assessing the Reliability of Complex Models
- Determining credibility of is the "goal" of VVUQ

Common Frameworks

Common Frameworks

1. EMDAP (CSAU)
2. Predictive Capability Maturity Model (PCMM)
3. NASA-STD-7009 (Credibility Assessment Scale)
4. ASME V&V 40

Traits

- List of criteria
- Small number of criteria (6-12)
- Few levels of evidence for each criterion (4-6)

“Credibility Assessment Levels” (NASA)

Verification: Were the models implemented correctly, and what was the numerical error/uncertainty?				
0 Insufficient Evidence	1 Conceptual and mathematical models verified.	2 Unit and regression testing of key features.	3 Formal numerical error estimation.	4 Numerical errors small for all important features.

Validation: Does the M&S results compare favorably to the referent data, and how close is the referent to the real-world system?				
0 Insufficient Evidence	1 Conceptual and mathematical models agree with simple referents.	2 Results agree with experimental data or other M&S on unit problems.	3 Results agree with experimental data for problems of interest.	4 Results agree with real world data.

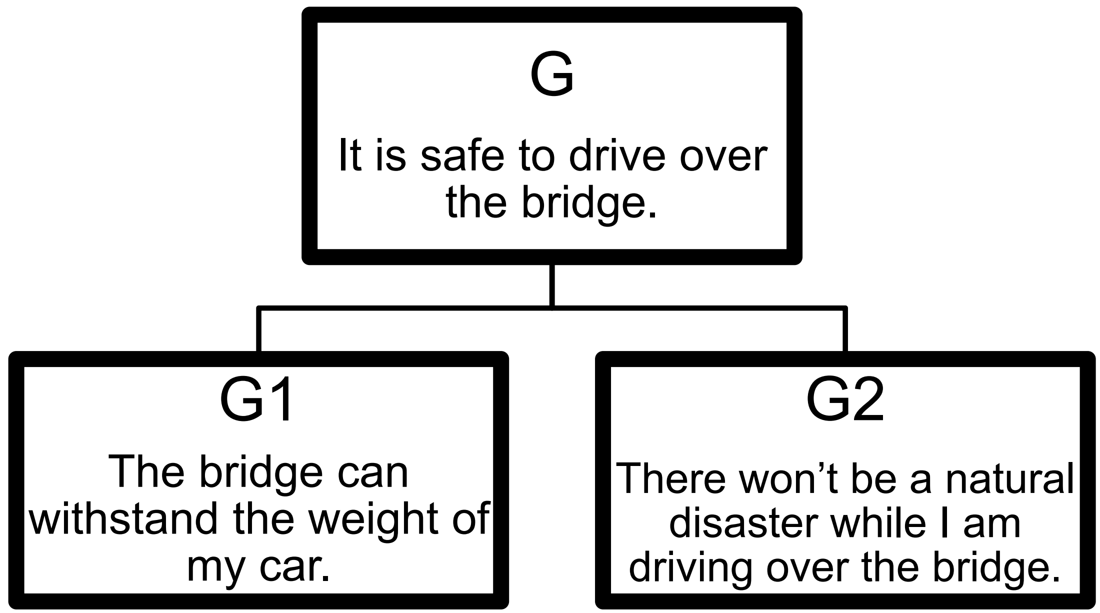
Goal-Structure-Notation

"GSN is a graphical argumentation notation…"

(GSN Standard, 2011)

Captures:

- **Goals**
- **Evidence**
- Assumptions
- Strategy
- Context…



Combine GSN with current frameworks

Driving over a bridge

G
It is safe to drive over the bridge.

G1
The bridge can withstand the weight of my car.

Level	Evidence
0	Don't think about it.
1	Someone has checked it.
2	I drove over it yesterday.
3	Someone will drive over it right before I will.
4	Engineering analysis of the bridge demonstrates a significant margin.
5	Current measurements of the bridge along with analysis of the bridge shows that it is structurally sound.
6	A recent bridge inspection showed that the bridge is structurally sound.

G2
There won't be a natural disaster while I am driving over the bridge.

Level	Evidence
0	Don't think about it.
1	In my experience, natural disasters are rare.
2	There hasn't been a natural disaster in this area for at least 20 years.
3	Bridge has been built to withstand any seismic activity. Weather forecast shows no adverse conditions expected.
4	A time traveler came from the future and confirmed that no natural disasters occurred on this bridge for at least 100 years.

Rules for Frameworks

1. Start with a Main Goal
2. Logically decompose the goal into sub-goals
   - Each sub-goal indivudally must be necessary
   - All sub-goals in a level must be sufficient

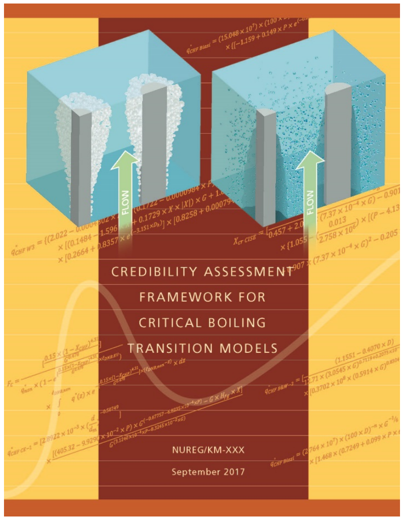
3a. Repeat Step 2 for each sub-goal.

- OR -

3b. Provide spectrum of evidence used to demonstrate the *base goal* has been met.

Chapter 2

Literature Review and Technical Background



Chapter 2

Literature Review

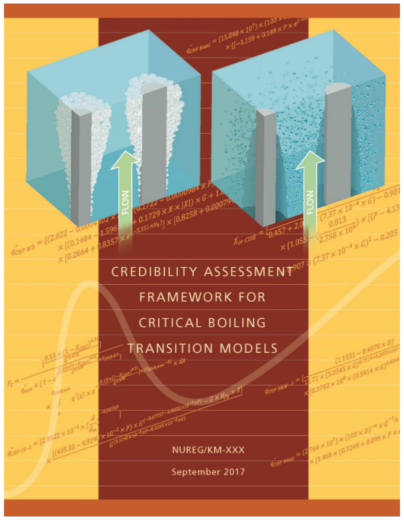
1. Selected Textbooks and Journal Articles.
2. Every CHF or CP topical report.
3. All associated regulations or guidance.

Technical Background

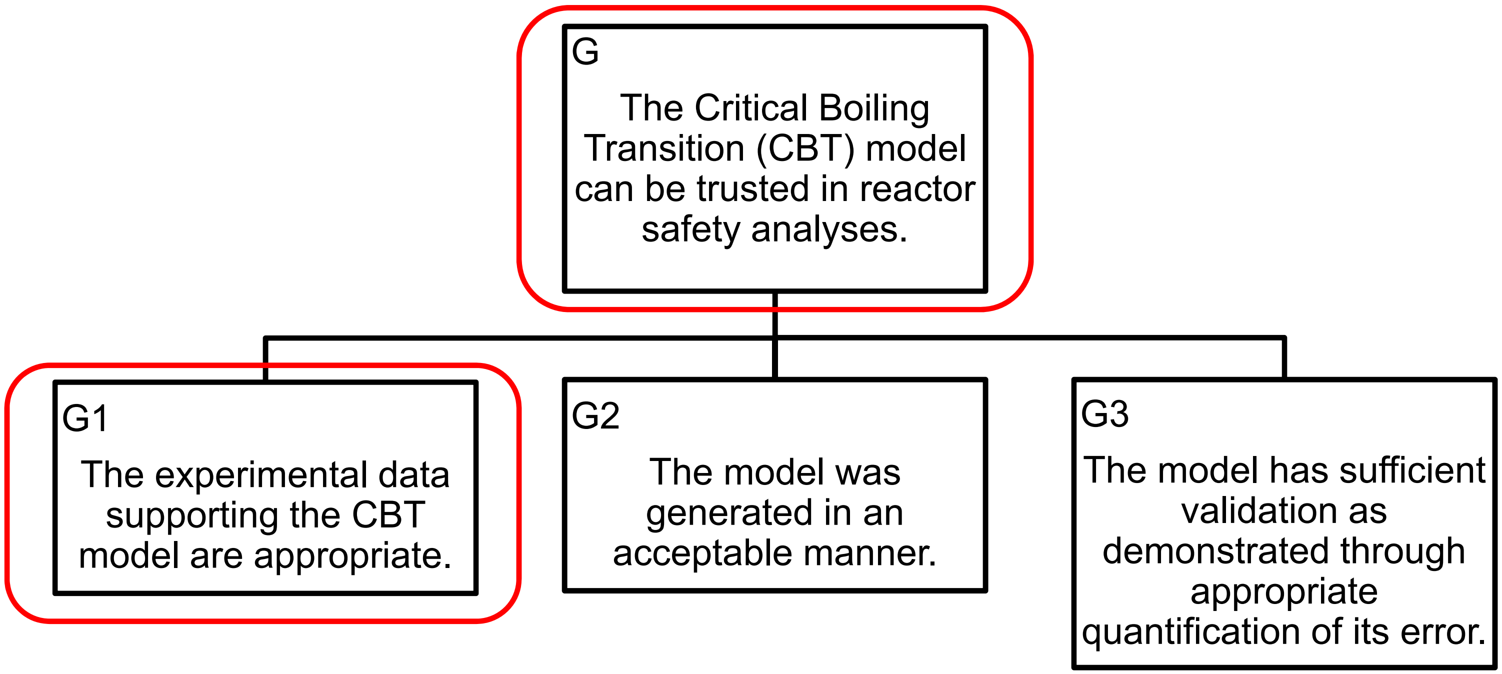
- Discussion of the relevant phenomena
- Discussion of how the phenomena is modeled
- Discussion of how the model is applied

Chapter 3

Credibility Assessment Framework



Main Goal (G)



G
The Critical Boiling Transition (CBT) model can be trusted in reactor safety analyses.
G1
The experimental data supporting the CBT model are appropriate.
G2
The model was generated in an acceptable manner.
G3
The model has sufficient validation as demonstrated through appropriate quantification of its error.

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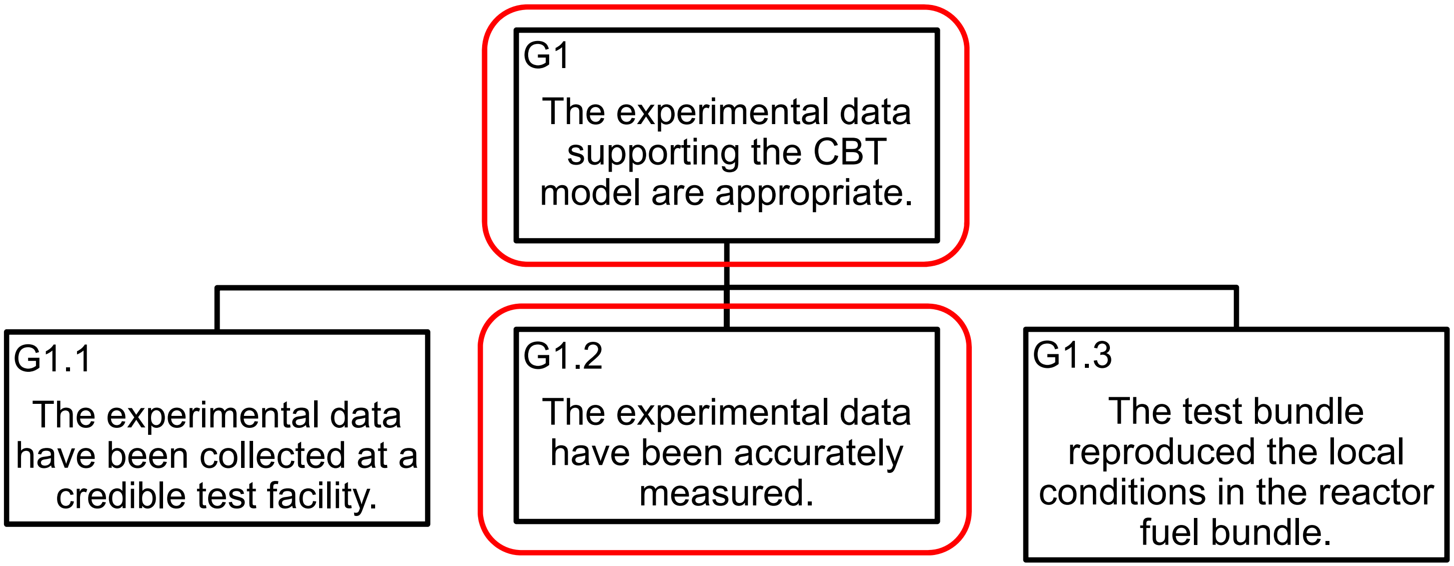
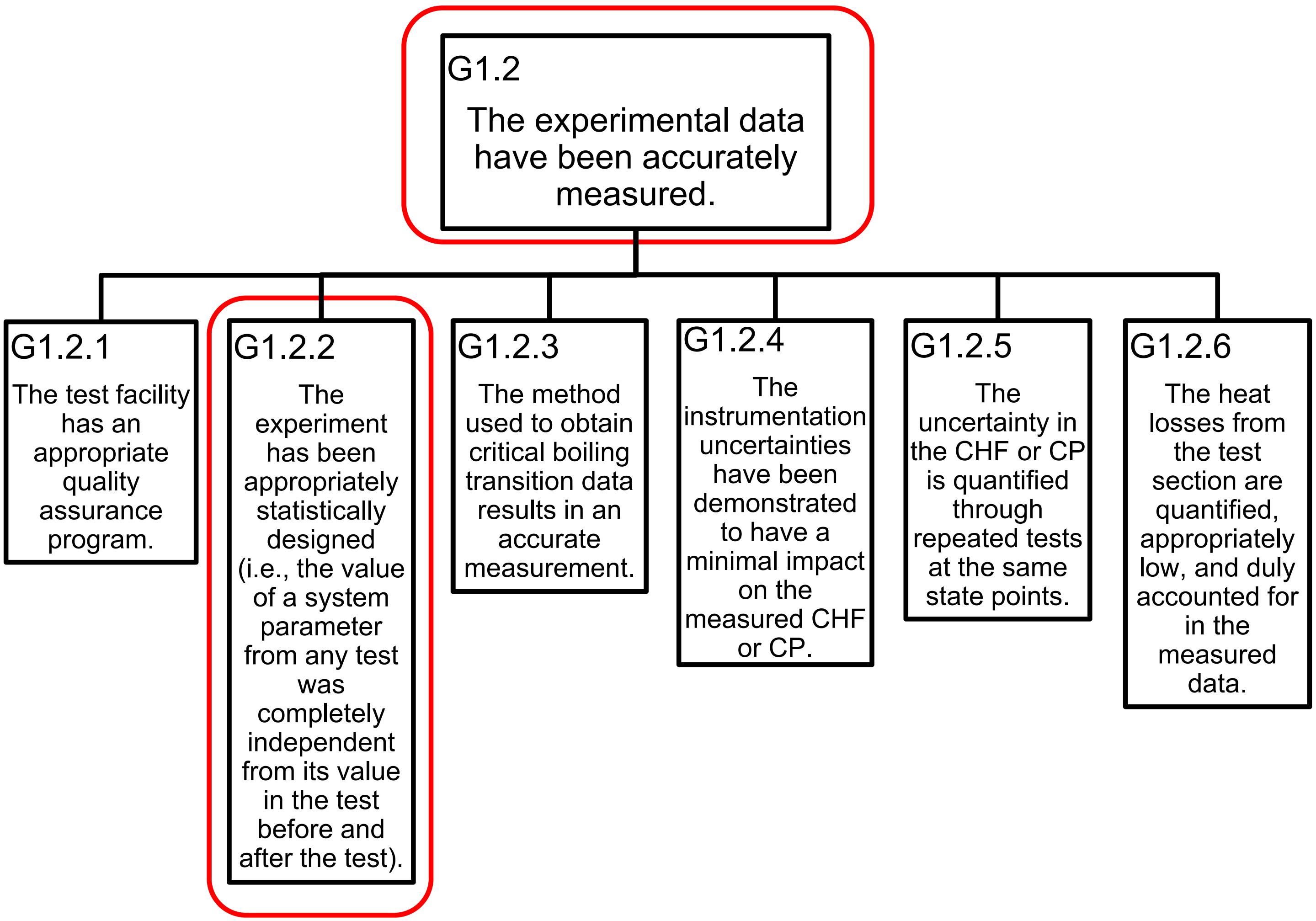
Sub-Goal G.1



Sub-Goal G1.2


G1.2
The experimental data have been accurately measured.
G1.2.1
The test facility has an appropriate quality assurance program.
G1.2.2
The experiment has been appropriately statistically designed (i.e., the value of a system parameter from any test was completely independent from its value in the test before and after the test).
G1.2.3
The method used to obtain critical boiling transition data results in an accurate measurement.
G1.2.4
The instrumentation uncertainties have been demonstrated to have a minimal impact on the measured CHF or CP.
G1.2.5
The uncertainty in the CHF or CP is quantified through repeated tests at the same state points.
G1.2.6
The heat losses from the test section are quantified, appropriately low, and duly accounted for in the measured data.

Discussion of G1.2.2

- Ensure that experimental methods do not introduce any statistical bias.
- Most methods assume independent and random uncertainties.
- Not strictly true, as you can't randomize input conditions due to large stresses on the test loop.

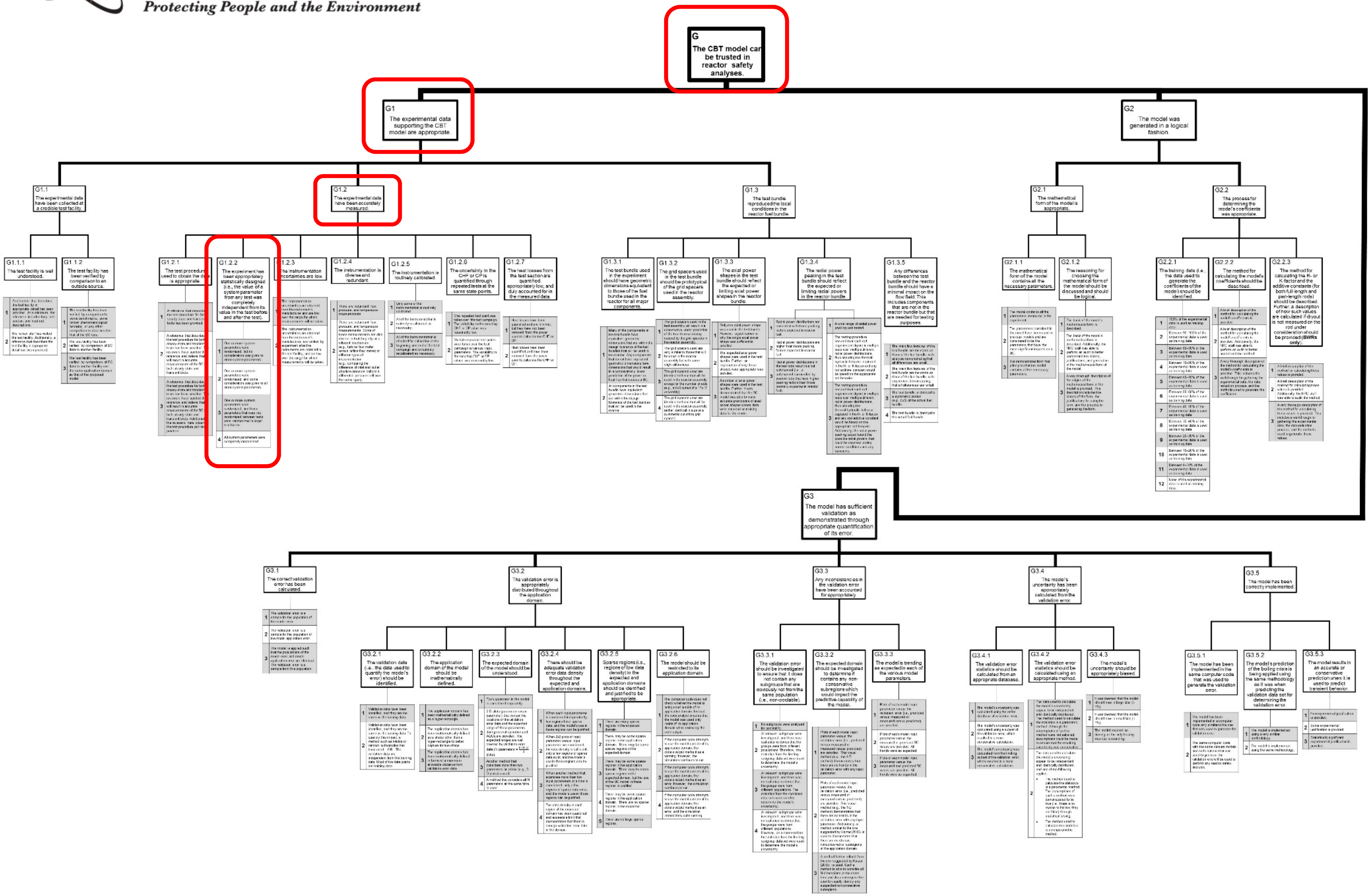
Possible Evidence for G1.2.2

G1.2.2	**The experiment has been appropriately statistically designed (i.e., the value of a system parameter from any test was completely independent from its value in the test before and after the test).**
Level	Evidence
1	One or more system parameters were randomized, but no consideration was given to other system parameters.
2	One or more system parameters were randomized, and some consideration was given to all other system parameters.
3	One or more system parameters were randomized, and those parameters that were not randomized between tests were randomized in larger test blocks.
4	All system parameters were completely randomized.

Historical Levels for G1.2.2

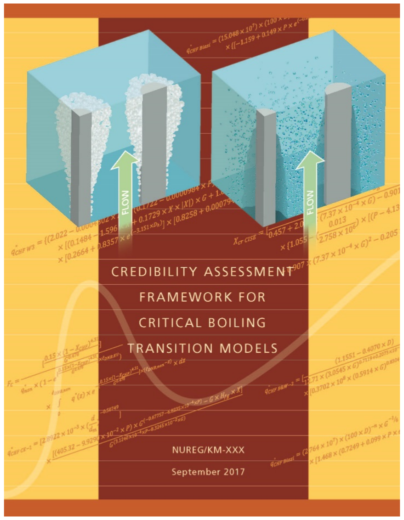
- Level 3 (is most common).
- Randomization has been generally limited.
- This is why it is important that there is another means to demonstrate no bias in the testing.

Critical Boiling Transition



Chapter 4+

Future Work



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Future work

- Credibility Assessment Framework for ~~Critical Heat Flux and Critical Power~~ **Data Driven** Models (ASME standard)
- Credibility Assessment Framework for Fuel Thermal Mechanical Models
- Credibility Assessment Framework for Large Break LOCA Models

Surprises

- **It works!!!**
- It saves significant resources!
- We haven't found any holes yet, but we can fix them if we do.
- Resulting SE's can be written very fast and are very similar to each other.
- It should work for anything…

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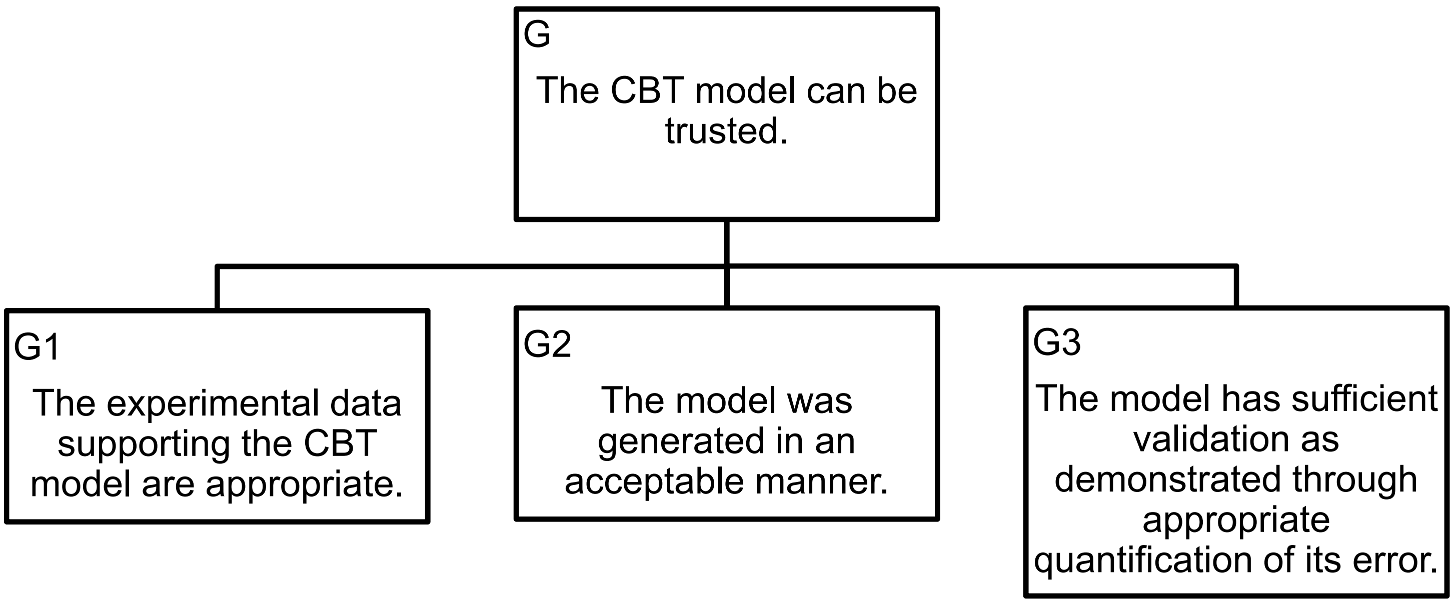

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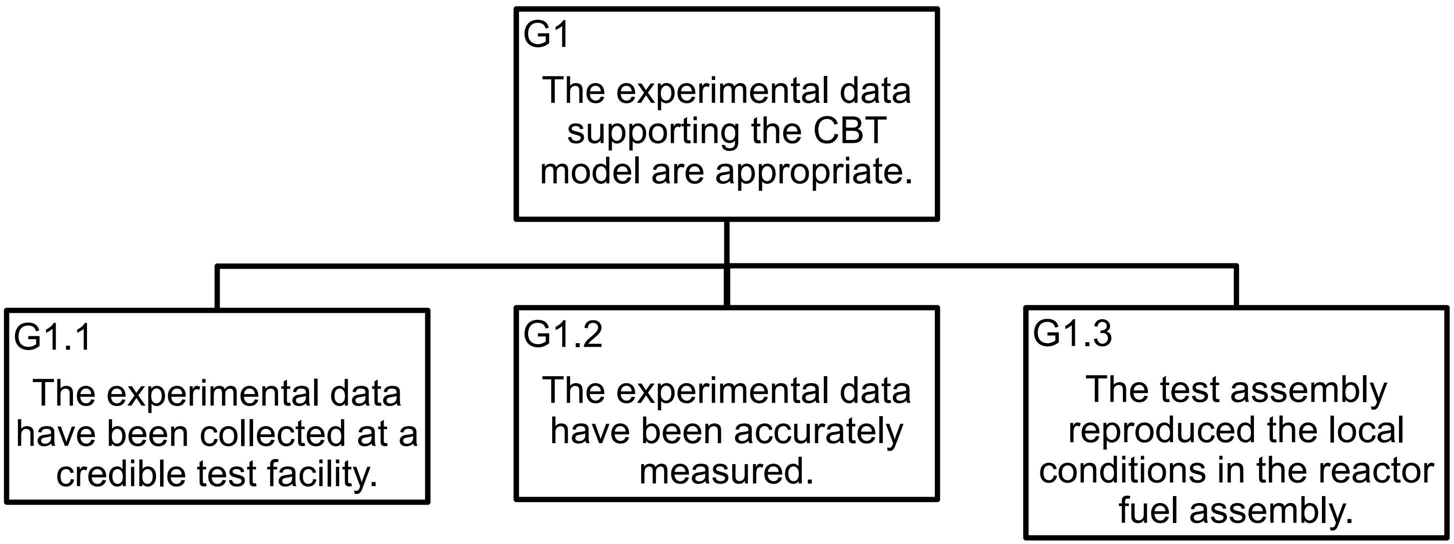
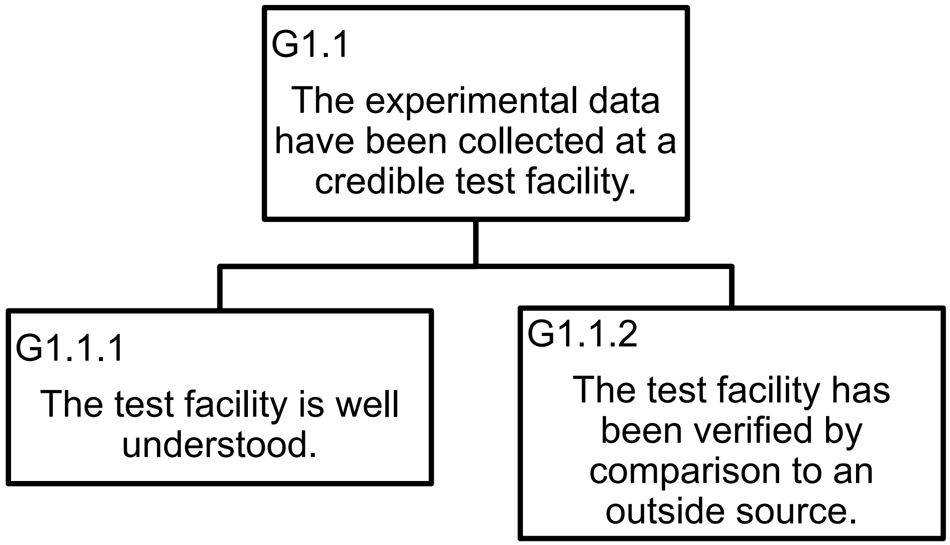
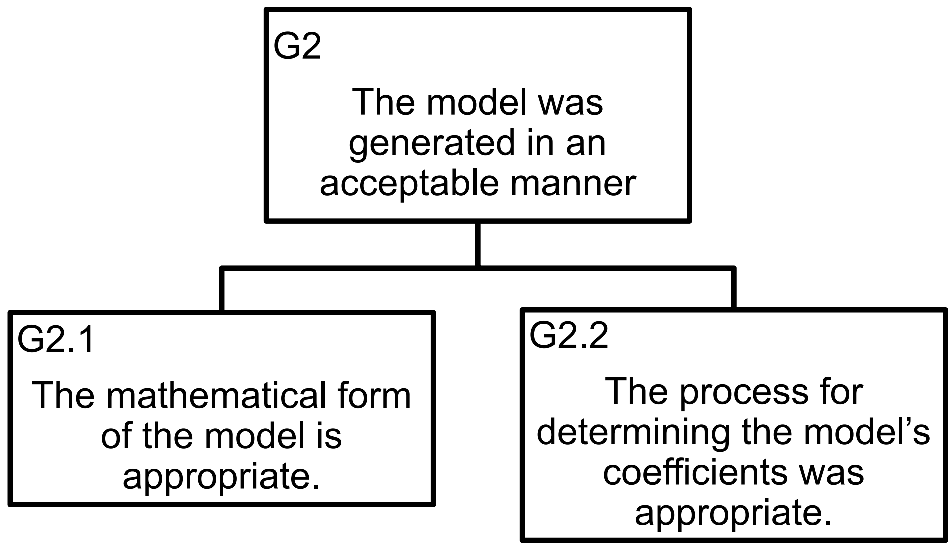
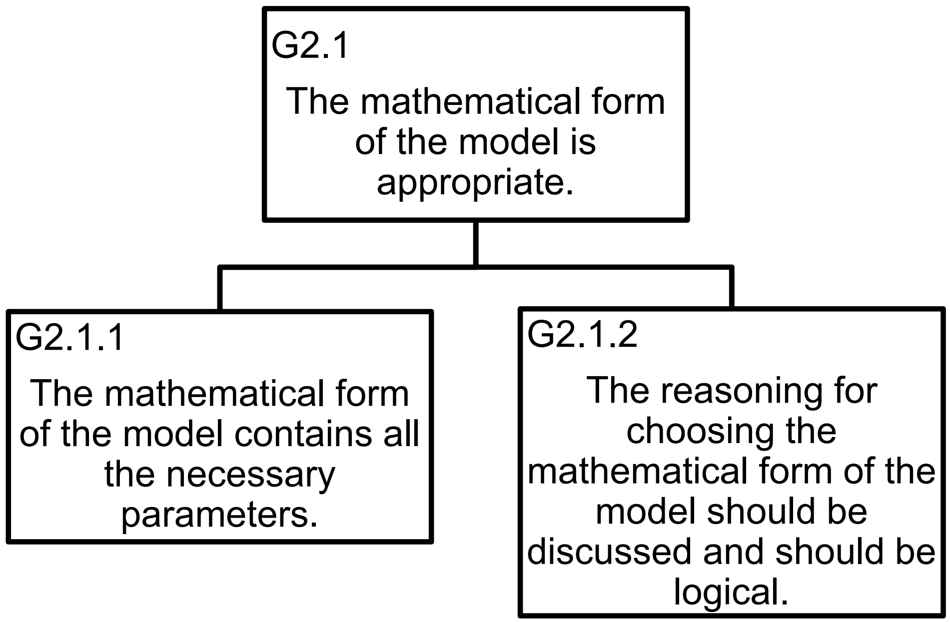



G1.1
The experimental data have been collected at a credible test facility.
G1.1.1
The test facility is well understood.
G1.1.2
The test facility has been verified by comparison to an outside source.

- **G1.2** The experimental data have been accurately measured.
  - **G1.2.1** The test facility has an appropriate quality assurance program.
  - **G1.2.2** The experiment has been appropriately statistically designed (i.e., the value of a system parameter from any test was completely independent from its value in the test before and after the test).
  - **G1.2.3** The method used to obtain critical boiling transition data results in an accurate measurement.
  - **G1.2.4** The instrumentation uncertainties have been demonstrated to have a minimal impact on the measured CHF or CP.
  - **G1.2.5** The uncertainty in the CHF or CP is quantified through repeated tests at the same state points.
  - **G1.2.6** The heat losses from the test section are quantified, appropriately low, and duly accounted for in the measured data.

- **G1.3** The test assembly reproduced the local conditions in the reactor fuel assembly.
  - **G1.3.1** The test assembly used in the experiment should have geometric dimensions equivalent to those of the fuel assembly used in the reactor for all major components.
  - **G1.3.2** The grid spacers used in the test assembly should be prototypical of the grid spacers used in the reactor assembly.
  - **G1.3.3** The axial power shapes in the test assembly should reflect the expected or limiting axial power shapes in the reactor assembly.
  - **G1.3.4** The radial power peaking in the test assembly should reflect the expected or limiting radial powers in the reactor assembly.
  - **G1.3.5** Any differences between the test assembly and the reactor assembly should have a minimal impact on the flow field. This includes components that are not in the reactor assembly but that are needed for testing purposes.


G2
The model was generated in an acceptable manner
G2.1
The mathematical form of the model is appropriate.
G2.2
The process for determining the model's coefficients was appropriate.


G2.1
The mathematical form of the model is appropriate.
G2.1.1
The mathematical form of the model contains all the necessary parameters.
G2.1.2
The reasoning for choosing the mathematical form of the model should be discussed and should be logical.

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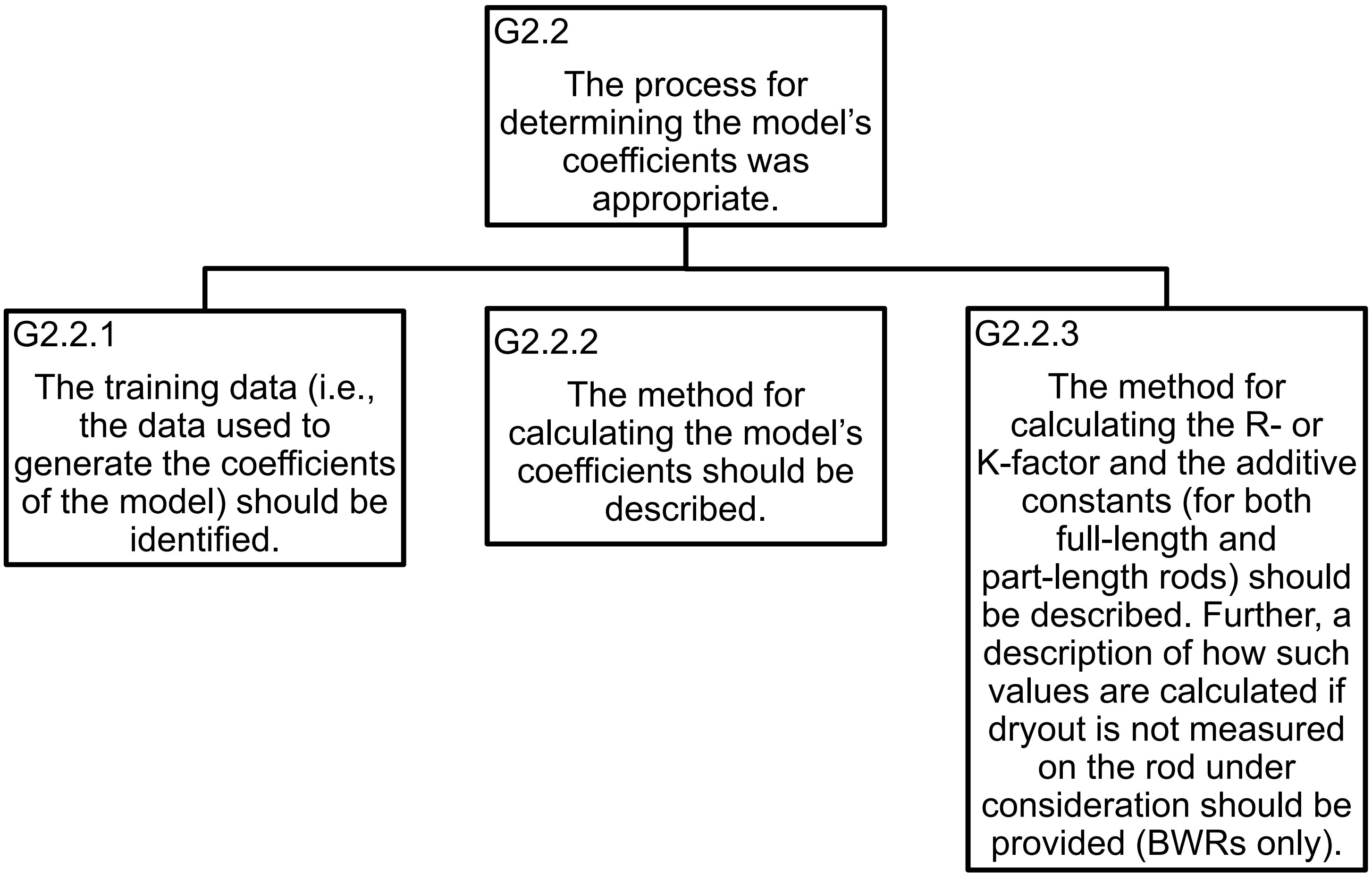
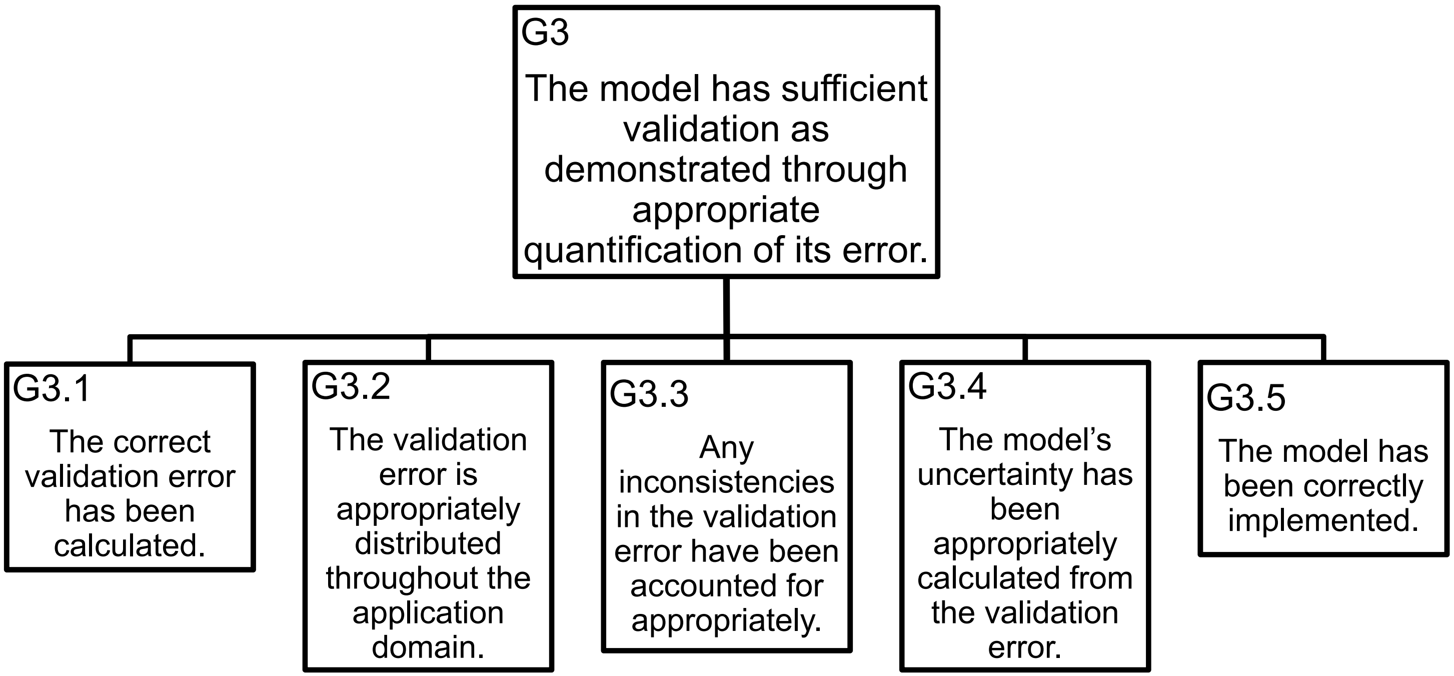
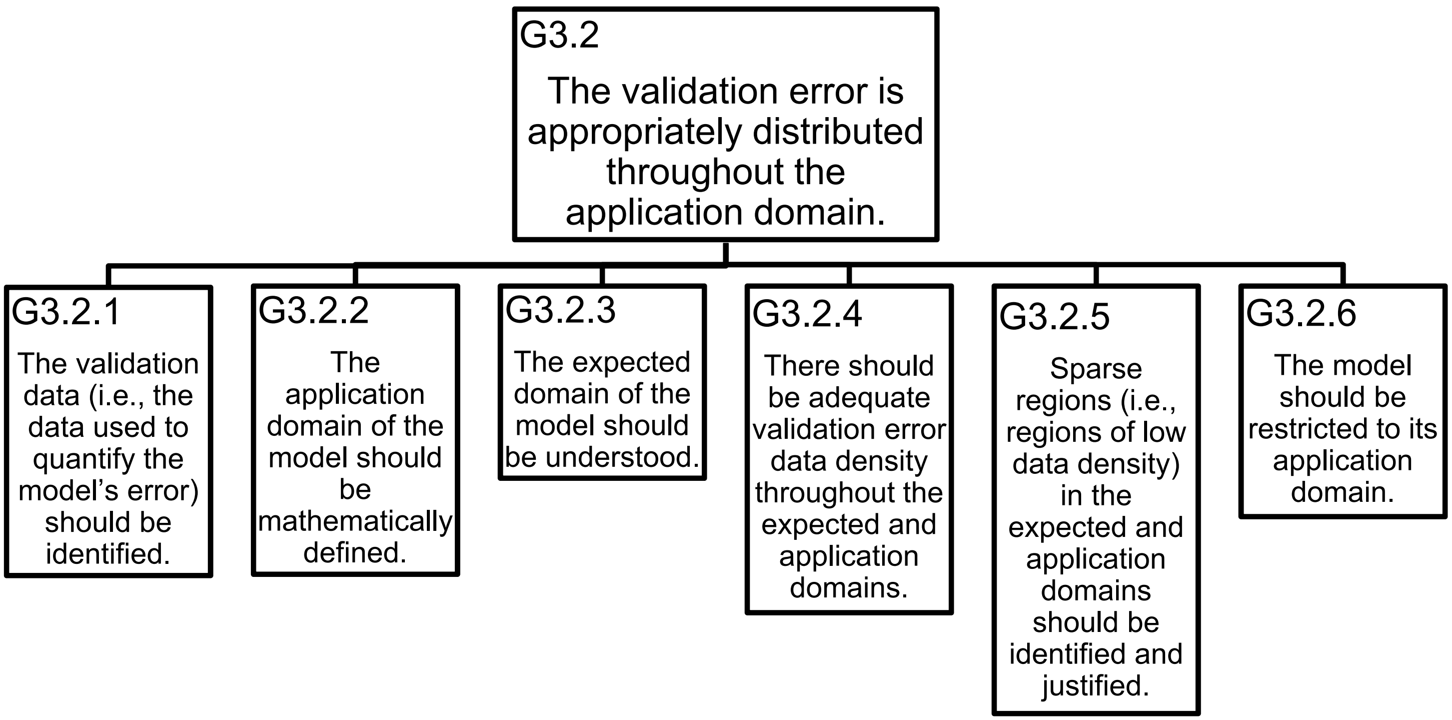



G3
The model has sufficient validation as demonstrated through appropriate quantification of its error.
G3.1
The correct validation error has been calculated.
G3.2
The validation error is appropriately distributed throughout the application domain.
G3.3
Any inconsistencies in the validation error have been accounted for appropriately.
G3.4
The model's uncertainty has been appropriately calculated from the validation error.
G3.5
The model has been correctly implemented.


G3.2
The validation error is appropriately distributed throughout the application domain.
G3.2.1
The validation data (i.e., the data used to quantify the model's error) should be identified.
G3.2.2
The application domain of the model should be mathematically defined.
G3.2.3
The expected domain of the model should be understood.
G3.2.4
There should be adequate validation error data density throughout the expected and application domains.
G3.2.5
Sparse regions (i.e., regions of low data density) in the expected and application domains should be identified and justified.
G3.2.6
The model should be restricted to its application domain.

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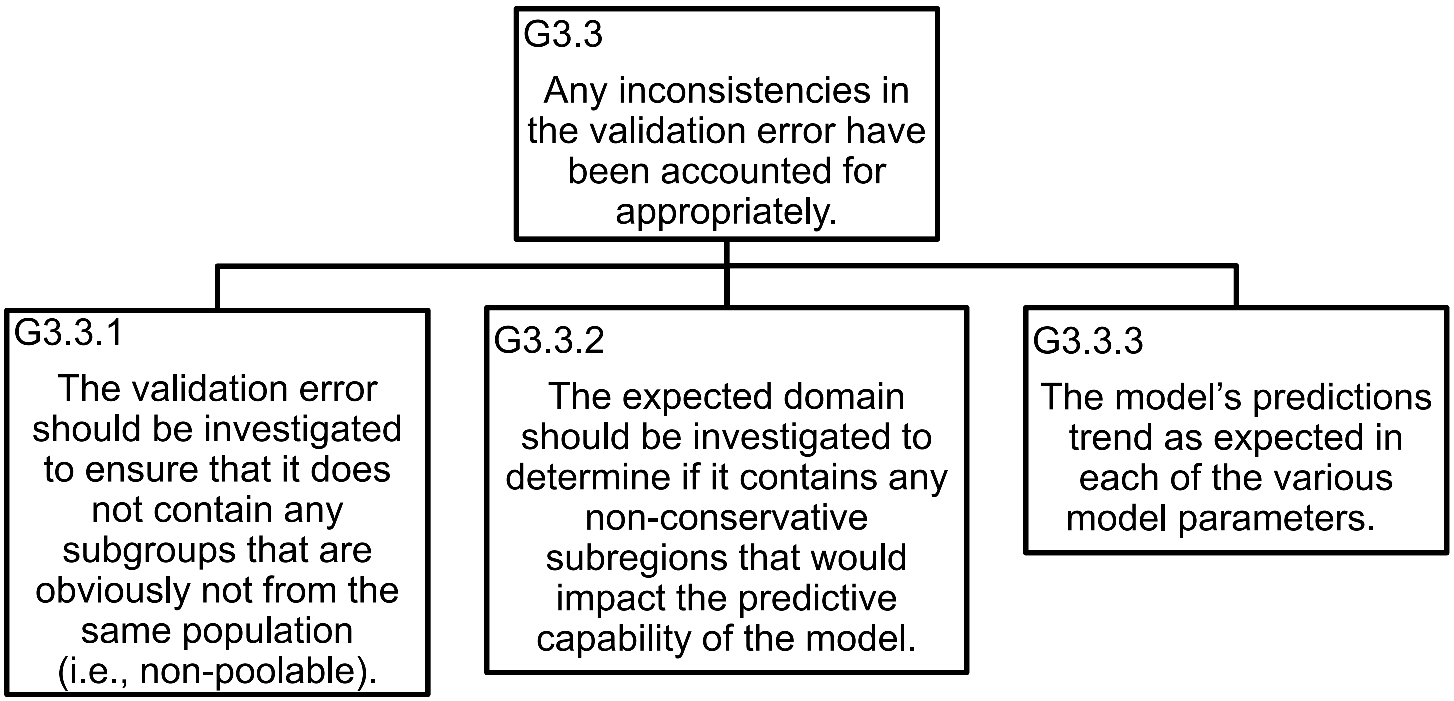

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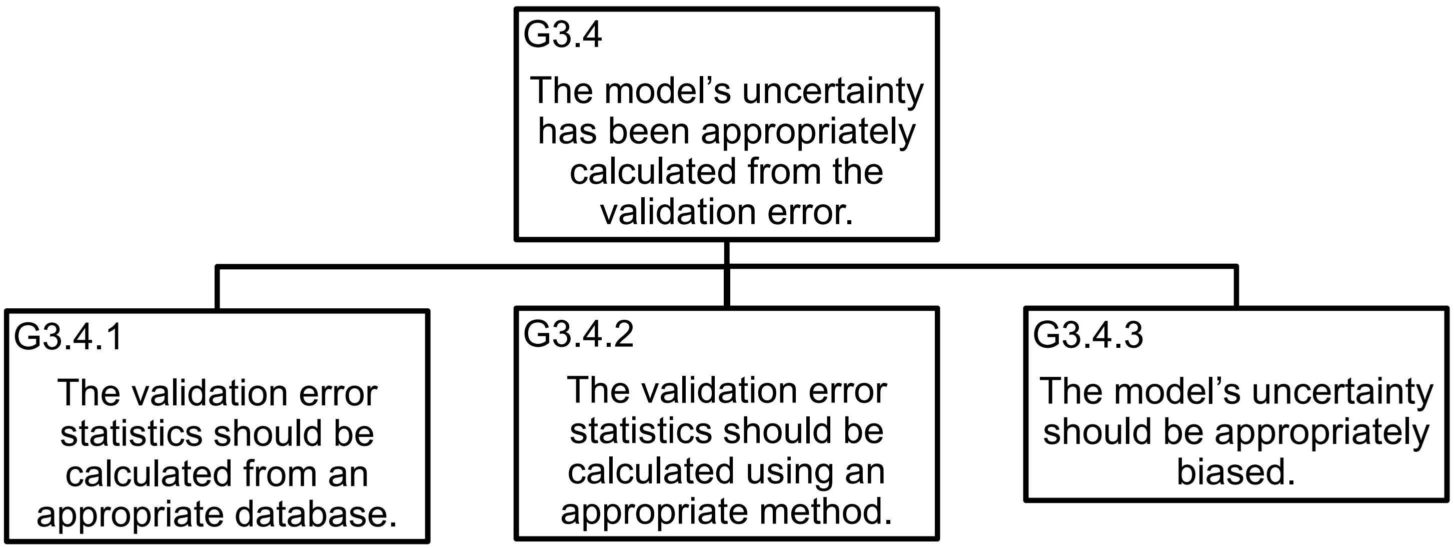

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