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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE ON RELIABILITY AND PROBABILISTIC RISK ASSESSMENT

MEETING

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THURSDAY,

September 21, 2006

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The meeting was convened in Room T-2B3 of Two White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 8:30 a.m., Dr. George E. Apostolakis, Chairman of the subcommittee, presiding.

MEMBERS PRESENT:

GEORGE E. APOSTOLAKIS
Chairman

MARIO V. BONACA
ACRS MEMBER

SAID ABDET KHALIK ACRS MEMBER

SANJOY BANERJEE ACRS MEMBER

HOSSEIN P. NOURBAKHSH DESIGNATED FEDERAL OFFICIAL

I-N-D-E-X

PART 1

Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications

NUREG-1824

PART 2

Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire

NUREG-1852

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

(8:30 a.m.)

MR. APOSTOLAKIS: The meeting will come to order. This is the meeting on the ACRS Subcommittee on Reliability and Probabilistic Risk Assessment. I am George Apostolakis, Chairman of this meeting.

Members are in attendance are Said Abdet Khalik, Sanjoy Banerjee, and Mario Bonaca. The purpose of the meeting is to discuss NUREG-1824, EPRI 1011999, verification and validation of selected fire models for nuclear power plant applications.

The subcommittee will also be brief on draft NUREG-1852 demonstrating the feasibility and reliability of operator manual actions in response to fire. The subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as a appropriate for deliberation by the full committee.

Dr. Hossein Nourbakhsh is the designated federal official for this meeting.

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

Register on September 8, 2006. A transcript of the meeting is being kept and will be made available as stated in the *Federal Register* notice.

It is requested the speakers first identify themselves, use one of the microphones, and speak with sufficient clarity and volume so that they can be readily heard. We have received no written comments or requests for time to make oral statements from members of the public regarding today's meeting.

We will now proceed with the meeting, and I call upon Pat Baranowsky of the Office of Nuclear Regulatory Research to begin. Pat?

MR. BARANOWSKY: Thank you, George, Dr. Apostolakis. I'm the Deputy Director in the Division of Risk Analysis and Special Projects, and we're pleased to be here today as we come to the conclusion on what we think was a successful project and one that's needed by both the NRC and the regulated nuclear community as we move toward the implementation of the National Fire Standard Act, NFPA 805.

The particular work we're talking about documented in NUREG-1824 involves the verification and validation of computer models used in fire analyses that both the NRC and the industry will be using as we implement that standard.

The work that was conducted over a several year period of time involved not only the NRC as you know, but the National Institute of Standards and Technology, the Electric Power Research Institute and their consultant, SAIC. And we have representatives from those organizations today that will make presentations on this matter.

The NUREG was put out for public comment, a 60-day public comment period earlier this year, and we've addressed those comments, modified the document and provided it to you before this meeting.

That concludes my introductory remarks, but I'd like to ask Gary Vine, the Executive Director for Federal and Related Activities at EPRI to give his introductory remarks.

MR. VINE: Thanks, Pat. I'd like to start with a bit of history on the cooperation that's gone on between EPRI and the Office of Research on both fire and on all the other issues that we've been working on together over the years. Some of you have heard the history before. For those of you who haven't, there was, under Shirley

Jackson's chairmanship, a major effort on strategic planning and direction setting initiatives that looked at a lot of facets of the NRC's operations. One of the areas that was looked at was research. And there were a number of concerns about the lack of collaboration because of limited budgets and so forth. And there was quite a bit of talk about increasing international collaboration, but not a lot of talk about increasing domestic collaboration.

So we discussed the options for doing that, and it was decided that even though there were some concerns about "independence" as a regulatory agency, there was perhaps a way we could collaborate significantly here in the U.S. between industry and NRC if we could devise a way to keep the research collaboration completely separate from regulatory decision making.

That was the basis – the policy basis for establishing an MOU between EPRI and the Office of Research in 1997. The framework was signed off that year with commission approval, and what it basically says is is that the two organizations can work together to collect the data necessary to resolve issues for both industry and NRC, to do that jointly and collaboratively, but that we're not allowed to, as we work together, get involved in any regulatory analysis or work that would lead to interpretation of how the data should be applied in regulatory decision making.

We simply complete the work on the data analysis on the science side of the issue. The data then goes to the program offices, NRR or NMS or whoever the regulatory user of the data is. Our data goes to the industry, nominally to NEI for them to decide how they think the data should be used in regulatory space, and our cooperation between EPRI and RES ends at that point. We, obviously on the EPRI side, will support any NEI and their understanding of what we did. RES supports the regulatory offices as they move forward. But the benefit of this approach, of course, is that we're starting with a common set of data and not arguing about our data's better than your data or whatever the holdup in the past has been. So it's a much more efficient way to approach things, and it's been very successful in a number of instances in getting a joint understanding of the problem developed early on before it gets into regulatory space.

Fire has been one of our best and longest examples of historic success. As you can see on the slide, the umbrella MOU was established in 1997. There have been probably 20 different addenda under that. There's about a half a dozen of them that are active today, another half a dozen that are still in existence but not as active in terms of ongoing projects, and a number of them, of course, have lapsed after completing the work.

The fire addendum was first drafted in 2001. It involved a lot of information sharing and other preliminary activities that we worked on together. One of the first major joint projects, of course, was the Fire PRA methodology that was briefed to you I guess it was last year and is now being widely used throughout the industry and throughout the NRC as the basis for moving forward on transitioning to the new fire regulations.

That effort was truly a joint effort where a team of EPRI staff, NRC staff, EPRI contractors, and NRC contractors worked together to produce a joint document. It went through all the formal reviews on both the NRC side and the industry side and is being widely used as I said.

The second major joint project that we've undertaken is the one that you're going to be reviewing today, which is our V&V of fire models.

This report is in draft form undergoing review. It's actually been reviewed, I think, extensively on industry and NRC side, and it's going through the final stages, including your review. There are a number of additional projects that we're contemplating and/or have already agreed to undertake in the fire area as a joint effort, including fire HRA, low power shutdown, a fire modeling user's guide and, of course, training is a big part of this, because there's a lot of work that has to be done to bring both industry and NRC staff and their contractor reviewers up to speed on all the work that has to be done.

So this has been a very successful arrangement between NRC and EPRI in gathering the data necessary for regulatory decision making and I think in the case of fire, probably more than some of the other areas. It has also been a successful area in developing jointly the methods by which the data would be used.

And so we hope to see more of this. We sure appreciate the whole spirit of cooperation that has existed on both sides as we've done al this work together. Appreciate the support we've had from the ACRS for this approach to getting the work done.

That's it. Thanks.

I'd like to, if we're ready to move on, Jason and Bijan will introduce the other team members that are here to present to you today.

MR. NAJAFI: Okay. I'm going to start with a program overview.

MR. APOSTOLAKIS: Introduce yourselves first, please.

MR. NAJAFI: My name is Bijan Najafi. I have managed and worked on EPRI's fire protection program for 15 years now, and I was the technical lead for the fire risk requantification project and this project as well.

MR. DREISBACH: My name is Jason Dreisbach. I am the Program Manager for this particular project in the Office of Research. I'm a reliability and risk engineer, a trained fire protection engineer. Bijan's going to start out the presentation, and we'll be back and forth throughout this first presentation that gives us a programmatic overview and technical approach. And Bijan will start.

MR. NAJAFI: We're going to start today with this first presentation. I tell you what the purpose of this front end is is that we will introduce to you this project from a program level: Why are we doing this, how we're going this, and what is our intended product, I mean where do we thing this product will fit, and what role does it play. So this is part of setting the stage for the technical discussions that come next. And I hope that this background gives you an idea of what kind of -- I mean sort of focuses the discussion of what you might be interested to know about this project.

MR. APOSTOLAKIS: What are you asking the ACRS to do?

MR. BARANOWSKY: Well after we finish this meeting, I guess the plan is to go to the full committee and get a letter endorsing the NUREG.

MR. APOSTOLAKIS: And then the NUREG is not a regulatory document?

MR. BARANOWSKY: No.

MR. APOSTOLAKIS: So there will be some regulatory guide later or?

MR. BARANOWSKY: Yes. I think Jason is going to be showing you how this fits into the regulatory picture.

MR. APOSTOLAKIS: Okay.

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: Okay, Bijan.

MR. NAJAFI: Yes. That's something we'll talk about, how this think fits into the regulatory picture. But basically, to give you a little bit of background is that -- I mean as you well know, that over -- it's been over 10 years or more that there is a move in the general community and nuclear power plant and fire protection in particular toward the risk-informed and performance-based regulation. And among many things that that kind of environment needs in a technical basis, one is basically reliable fire model or modeling tools that can be used.

And those basically tools can support either existing regulation -- there's a number of areas -- through the exemption request that has been practiced that these models have been applied. On the Reactor Oversight Process and SDP, these models need to be applied. And under the NFPA 805 licensing basis, there is a place for the use of the fire modeling. In order for these fire models to basically fulfill that role, there is a need to understand basically their predictive capabilities within how they can address issues that are specific to the nuclear power plant fire scenarios, and to the extent possible, our intent was to be able to quantify that predictive capability. So that's the first objective. Next slide please.

MR. DREISBACH: Building on what Bijan was talking about and the question that Dr. Hothlock has asked about where this fits into the regulatory framework, we put together this relatively simple slide of where this particular document fits into the whole regulatory framework. You see it down on the lower right-hand corner where it says NRC-RES-EPRI Fire Model V&V. This is basically providing some sort of methodology document or, more accurately, a technical basis document for this. And it's in line with the PRA methodology that the NUREG/CR 6850 EPRI 1011899 document. And as you move up the chart, you increase the regulatory decision making process, so the next level is the standards that sort of point to the lower documents as something that needs to provide some technical basis. So you have the PRA standard on one side. And you have the NFPA 805 standard, and then as you move further up, you get into Reg Guide space where now we're trying to implement the actual rule which is at the top level.

Now you can add a lot of other things in this diagram, like the Appendix R rule. You can other Reg Guide, like Reg Guide 1.200 or Reg Guide 1.189. You can add other types of standards and technical bases documents, like the SDP or other PRA-type documents.

But this is sort of where we fit in, the document that we're creating, how we fit into the overall regulatory structure.

MR. APOSTOLAKIS: This is not -- Bijan mentioned the significance of determination process and so on. You are focusing on 5048-C?

MR. DREISBACH: That was the original impetus for this document, because the standard, the 805 standard which is endorsed by the rule making requires verification and validation of fire models. However, models are also used in the other types of analyses conducted under the existing rule making or the previously existing rule making under Appendix R, such as the SDP, the ROP-type frame PRA-type analyses, or even the deviation exemption process. We have seen applications that use fire modeling in those situations even before we've had the endorsement of NFPA 805. So this tool that we've created can be used in the normal regulatory space under Appendix R, but we focus a use or the impetus originally was for use under NFPA 805 rule making kinds of things.

MR. NAJAFI: So coming back to this project, the specific one other question that may come up is that one, there are enough V&V'S out there. Why did we do this. Why did we take out another V&V for this particular purpose. I guess the answer to that question is that we wanted to make sure to satisfy a couple of fundamental -- be able to answer a couple of fundamental questions. It's that the nuclear power plant fire modeling has some attributes or issues that may be unique to itself. We wanted to make sure that we basically match those capabilities of those code to answer to specific questions. Some may be the same. Some may be unique. So we wanted to make sure how we can match that. So that was one of the primary objectives, and you will see it later on in our presentation how it comes about through our approach, the approach or the process that we took to accomplish that.

MR. BANERJEE: Excuse me. Tell us a little bit about what issues are specific to.

MR. NAJAFI: We'll come to that a little bit later, but for example the issues that may be in a atrium, in a mall, may be egress related, but the issues we have is cable fires. We had issues in switchgears. We have situations in power plants that because of a more confined or compressed geometries, the affect of calculated plume temperature is more important than a smoke migration, whereas in a hospital, generating smoke and migration smoke may be more important to them in a different environment. So we have to first understand what our scenarios are, what our attributes of those scenarios of interest are to make sure that we validate for those particular. And I hope that becomes more clear as we go, because we talk about those scenarios.

MR. BANERJEE: You will talk about --

MR. NAJAFI: We will talk about those specific scenarios and attributes that we're interested in.

And the second piece that was somewhat critical to us is that to the extent that it can be supported by the data, we intended to be able to come up with some quantitative measure of that predictive capability. Why is that important to us? Because in some of these cases we're facing, these models are being used in what I call a post-design as-installed condition. So it is -- we're trying to evaluate something that is inexistent, it's not a design.

So for us, how much margin we have and be able to have an appreciation of that degree of margin, it is important. Some of that margin may be, for example, if we find that these are 25 percent off, whereas in the design stage, that may not be important because you can deal with it in safety factor. In an as-built situation, it may be important. It may be important, that margin. So we wanted to be able to characterize that accuracy to the extent that we can in a quantitative way.

And also, I men because we selected a number of codes that were mostly used in the industry at the current time, in our industry, we wanted to establish a process that, if necessary, in the future can be followed for other models, other codes, it's not limited to these experiments. So it's more of a -- just as much developing a process that it is to validate these particular codes.

MR. APOSTOLAKIS: At which point will you tell us what predictive capability is?

MR. NAJAFI: We will hope to tell you that during this. We will start by the end of our basically technical overview. We will tell you predictive capability by -- what I'm hoping is that we tell you these are the scenarios that we are interested in, these are the attributes of those scenarios we're interested in. For example, the attribute may be a plume temperature of an oil fire in a small room, and then we define the predictive capability meaning --

MR. APOSTOLAKIS: There is an important table in Volume I --

MR. NAJAFI: Yes.

MR. APOSTOLAKIS: -- which you will show it to us at some point?

MR. NAJAFI: Yes, definitely. In Sections 2.3, 2.4, 2.5 and 6, those are areas that we will discuss here later on today in maybe I would say half an hour or no more than that, that it basically says how do we define, how do we characterize that predictive capability. That's an important part, and we intend to discuss that today.

The next couple of slides is intended to give you basically a picture of our recognition of what we thought were the challenges of this project, and how do we assemble this team to make sure that we have the right team, because, I guess, like any other project, the first challenge is to know the problem you're facing. That's the number one question. And if you understand the problem you're facing, then you're second challenge becomes to put the right team together.

MR. APOSTOLAKIS: That's my problem, Bijan. I don't know what you're trying to get at. What is the problem? You said 805, PRA's. Okay? Now as far as I know, what we need there is the probability distribution of temperature at some point, or the time evolution and so on. So I don't know that you actually do that.

MR. NAJAFI: In a PRA space, you have to -- you have multiple -- you have a – conditions generated by the initial fire. That is determined by the size of the fire, location of the fire. We have distributions for that. We deal with that. And if you recall in the NUREG 6850 EPRI 1011899, we described the issues or uncertainties related to this inputs, the size of the fire. Once you get the size of the fire, you have to analyze the progression of the fire, how does the fire grow, how big did it get, and what kind of damage it causes. That is where the fire model comes into the picture. That's just, let's say CFAST, for the sake of argument.

Now we define the input for CFAST and the uncertainties associated with it in some other document. When it comes to the damage and the effect or the use of the output of the CFAST, it's damaged criteria. There is a distribution associated with that that is generated from fire testing. What is our understanding of the response of let's say a cable to certain temperature exposure or flux. The problem in the middle we're trying to deal with is what is our understanding or uncertainty, for lack fo a better word, of this middle piece of the model.

If we happen to put the exactly correct heat release rate and all inputs into it, and we got the temperature that we got out of it, how much uncertainty have we introduced because of the model uncertainty, of the uncertainty of the CFAST itself. This is what we're trying to deal with in this project, the uncertainty of CFAST.

MR. APOSTOLAKIS: But you don't do that. You're giving me colors. You're telling me zero plus.

MR. NAJAFI: We'll get to that. Well, we'll get that.

MR. APOSTOLAKIS: I have no idea what to

do with that.

MR. NAJAFI: That's -- We'll get to that.

MR. APOSTOLAKIS: Warn me.

MR. NAJAFI: Yes, I know. Colors are extremely important. I have no idea how to use them. I haven't seen them anywhere else so.

MR. NAJAFI: We will come back to that at the --

MR. APOSTOLAKIS: Well, the thing is that you keep talking about predictive capability. In previous slides, you said quantitative, if possible and so on. And then I look at your final result, and it's yellow plus yellow plus green, yellow, and not applicable. I have a big problem with that.

MR. NAJAFI: Yes. Well --

MR. APOSTOLAKIS: I have a huge problem with that. I don't know what to do with colors.

MR. NAJAFI: I think I can say as a user what to do with those color. It was our intent --

MR. APOSTOLAKIS: I'm waiting to hear you.

MR. NAJAFI: Okay.

MR. APOSTOLAKIS: I'm anxious to hear

what you have --

MR. NAJAFI: It is true that it's a challenge. Ideally, ideally, we wanted, as research people, to provide a distribution, but it is my understanding, and I think that this team can speak for themselves, we tried to build a consensus. Neither the evidence gives us enough comfort to give you that level of precision. It does not. We tried, and we were not able to get to that level of precision. And --

MR. APOSTOLAKIS: Okay. We'll come back to this --

MR. NAJAFI: -- that is a desired -- it's -- you may be -- you're correct that that's the desired outcome, but can we accomplish that level of precision at this time, it is my judgment that we could not.

MR. APOSTOLAKIS: Amount of time? Is this progressing or continuing or -- Yes, sir, who are you, and tell us what you want to say.

MR. JOGLAR: My name is Francisco Joglar. I work for SAIC. I'm part of this team.

MR. APOSTOLAKIS: Good.

MR. JOGLAR: The question you're raising suggests to me that in a risk, in a Fire PRA, ideally we would like to see something like my fire mole is predicting this number, and I would associate that number which ends up as some damage to a probability of that thing being correct so that we could use it. This didn't recognize that need, and we have put together a method and a way of organizing data that we think eventually will support that goal. Okay? And I've seen methods from all uncertainty that would give us that this doesn't get to that point, but in those methods that I've been familiar with, the way we have organized the data and developed this method will support.

MR. APOSTOLAKIS: When will it do that?

MR. JOGLAR: I'm just a technical person. I don't have an answer for the when, but I am confident that it can be --

MR. APOSTOLAKIS: You're asking this committee to bless this document, and I'm questioning its usefulness. Are you telling me in the future, it will be useful?

MR. JOGLAR: It is still useful now because there is -- we did add a section that explains how to use these results.

MR. APOSTOLAKIS: And I read that section, and I'm not sure I like it, because not only do you give me colors, you're asking me to go back and make sure that the data that were used in the tests and the data in my scenario are consistent with each other. You're asking me to do too much. You're asking me to go back and reproduce everything you've done. Maybe it's too premature. I'm just warning you that the color business will be a central point of the discussion today. So let's go on, Bijan, because I don't want to destroy your presentation.

MR. NAJAFI: No. I know that that is a challenge. That's why I raised it as a big challenge.

MR. APOSTOLAKIS: I'm sure you're aware of it. I mean you guys weren't born yesterday but --

MR. NAJAFI: Yes. And I think --

MR. APOSTOLAKIS: That's not my problem too.

MR. NAJAFI: Yes. More than you -- I shouldn't say that, but we understand.

MR. APOSTOLAKIS: You understand that problem more than I understand it.

MR. NAJAFI: No, no.

MR. APOSTOLAKIS: That's very good,

Bijan.

MR. NAJAFI: No, no. I think it's a -- I understand that that's a very important thing, and that's why I think.

MR. BONACA: Yes. And more than only the simulations and what do you do with this for the PRA. I must say that reading this, when I got to the end of it, knowing the FIVE for example has been used extensively in the plant applications, new estimations, I am puzzled by this table, because I could not -- I really wondered at the end of that. I said, you know, how can they make projections and calculations. I mean what kind of information are they getting from I was just thinking of FIVE or FDT. And, you know, you're left with that question in your mind. I mean all we can say is n/a, n/a, n/a, n/a about all these attributes or parameters. And you have a couple of yellows there plus or minus, so it says be cautious on how you apply it. What does it mean be cautious? I mean I'm left with all those questions.

MR. NAJAFI: No.

MR. APOSTOLAKIS: That's my problem, too. I look at this multi-volume report, and all I get out of it is that I have to be cautious.

MR. BONACA: I really wouldn't know how to be cautious about some of this stuff.

MR. APOSTOLAKIS: But I think we should let Bijan go on, but I think this was --

MR. NAJAFI: I think we will try to attempt -- I will try to attempt --

MR. APOSTOLAKIS: Okay. Go ahead.

MR. NAJAFI: -- to tell you how I would use it if I was the user at the end, those colors --

MR. APOSTOLAKIS: Okay. Maybe you'll see my point.

MR. NAJAFI: -- and we'll see where it goes. I mean I guess the bottom line is that my opinion, we're not where we -- at the precision that you're talking about, but I think we have results that it's useful. We'll talk about that. But basically the challenges that we faced, I mean in here, is -- I mean some of the underlying reasons for those difficulties that -- a couple of fundamental things is that what is the appropriateness of the model to the fire scenario. I mean we have a fire scenario that we know what it wants. We need to understand how close and how well these fire model that we are using represent those scenarios. And this is one challenge. This is hard to basically -- we know in many cases, they may or may not. In fact, you'll see examples. There are examples that are listed in some other parts of the NUREG 6850. There are fire scenarios that there is no current models to deal with it, like a high energy arching fault or the cable fires are some of those examples.

The second challenge is that basically to be able to tie in or understand the appropriateness of the experiment or experiments that we're using to the fire scenarios and obviously --

MR. APOSTOLAKIS: Excuse me, Bijan. My understanding is from reading the reports, and maybe it's a wrong understanding, you use the results of existing experiments, or did you actually fund running experiments?

MR. NAJAFI: A combination of both. We used an existing experiment that was done in the 80's, and there were a number of experiments that I would -- we'll talk about -- Anthony will mention some of those -- that were done at NIST that were used in the last couple of years.

MR. APOSTOLAKIS: But this international --

MR. NAJAFI: That's included. That's -- basically that's what I --

MR. APOSTOLAKIS: But that was done as part of this study or was there a separate --

MR. NAJAFI: I would let NRC speak whether that was done for support of this --

MR. DREISBACH: It was for support of this project. We – It was an exchange program more or less whereby we created a set of experiments that NIST performed for us, specifically for a V&V document. And we traded that data with the International folks for the same purposes. So they conducted experiments for their own verification efforts and provided that data to us. And we in turn provided our data to them. And that's how we obtained the data that we did to use in this project.

MR. NAJAFI: So I guess the answer is yes, there are some tests that were done for this particular project. But I guess the message there is -- I mean there is not today and not probably for a long time enough experiment to mimic all the scenarios that we need to deal with. I mean --

MR. APOSTOLAKIS: And not enough experience, actual operating experience --

MR. NAJAFI: And there are a few -- there are some, like for high energy arching faulty, there may be some operating experience, some evidence or certain things, but there are really not that many to go by, so that's the other challenge. So --

MR. BANERJEE: Is this very different from what happens in chemical plants? There's a hug database there.

MR. NAJAFI: The scenarios, it could be different. Because the scenarios in a chemical plant -- I'm by no means an expert in a chemical plant -- but they are -- they should be, if they're not, more concerned about toxicity and what is generated in a fire as opposed to the temperature of the radiation of a fire. I mean --

MR. APOSTOLAKIS: Well, they're interested in both, because vessels fail due to external fires. And there's a lot of concern about vessel failure which can actually propagate and cause other vessels to fail. So there's a lot of concern about heat and radiation, especially on external fires. Of course, a lot of data on internal fires, too.

MR. NAJAFI: We could have used -- I

mean experiments -- I mean we went through and defined out our scenario, because we wanted to know what are the issues that it's facing to the nuclear power industry. But then when we started looking for experiments to use, we basically -- I believe we did look first into the experiments that were done uniquely for nuclear power plants, and we did not cast a wide net to find out if other industries, aerospace, chemical or other people -- I mean NRC may have done that, but we did not, because we were -- I mean at the time, we felt that a sufficient test was done in Sandia, at NIST, way back. We had a number of tests to go by, but our challenge is that we do not have at the time even tests that can I mean clearly represents the attribute of a nuclear power plant fire. I mean to go even outside.

MR. APOSTOLAKIS: So you have to tell us what's so unique about that, right..

MR. NAJAFI: Yes.

MR. APOSTOLAKIS: You're going to tell us?

MR. NAJAFI: We're going to try. We're going to try.

MR. APOSTOLAKIS: Right.

MR. NAJAFI: We're going to try what's

unique about that.

MR. APOSTOLAKIS: And when you have these models, to validate them, I'm sure that your experiments are not just plant specific, right.

MR. NAJAFI: Oh, absolutely.

MR. APOSTOLAKIS: They should have some generic importance?

MR. NAJAFI: Oh, yes. I mean --

MR. APOSTOLAKIS: Then why do you neglect databases in other industries which could be generically important?

MR. NAJAFI: Because the generically, then it has to apply through the industry. It's a difference.

MR. APOSTOLAKIS: You have to show us what's different generically between your nuclear fires and your chemical fires, right?

MR. NAJAFI: I will try to explain what I think is the attributes of the nuclear power plant fire scenarios. We will try to explain that. And I guess how is that different from a chemical industry, I will only can speculate. I mean I can –

MR. APOSTOLAKIS: Because you know that the insurance industry has been very active in this area, and two of the largest losses come from either fires or explosions in the process industry. And because of that, this is a very, very extensively researched area, and there are, you know, whole companies devoted to this.

MR. NAJAFI: In fact, we did have research for -- we did look into NEIL, Nuclear Energy Insurance Limited, the insurance company that basically insures nuclear power plants, but not general, non nuclear insurers. But we did ask and get information from the nuclear insurers. But, again, I mean you have a point that why did we not use non-nuclear experiments potentially out there, and all I can say it was basically a limitation of resources, and we chose to use experiments that we had that were conducted for nuclear facilities.

MR. APOSTOLAKIS: Particularly, as you were saying, there's a paucity of data, right?

MR. DREISBACH: And I think there still is, because some of the experiments that you might talk about outside of the nuclear industry and related to other industries. Not only did we want to characterize the nuclear industry type of fires, we wanted to make sure these experiments captured the appropriate data by which we could use to compare with the models. And sometimes in those types of experiments, we don't get the data capture that we would need to fully evaluate the model that we're dealing with here, that we wanted to deal with. So there is a lot of --

MR. BANERJEE: So is this just the fueling or you have some quantitative --

MR. NAJAFI: A good example of it is that -- I mean we are concerned about small long duration fires. I don't know if that's something that a chemical is interested in. I guess the bottom line is that for us, it was an effort to go and look at those experiments and make a case that they are valid, because any data that we use outside of our industry, it is our responsibility to make a case that it is valid. We're not going to automatically assume that it's valid. We have to make a case that it does apply to our industry. We have to make a case.

MR. BANERJEE: Yes, but presumably these models have some fundamental science in them, and if they do, then experiments which are directed towards clarifying these fundamentals are valid whatever the industry. I mean a fire is a fire at the end of the day. Whether the control room is a chemical control room or a nuclear control room, there are going to be things which have a common characteristic.

MR. NAJAFI: You are correct that if it is happening -- if there is fire test in a chemical control room, then it may be applicable to our --

MR. BANERJEE: I just don't know. I'm saying that it's of concern that data which might be valuable in a situation where data is expensive to get has not been evaluated. And if you come up and say, it's not valuable for these reasons, these data exist, that's something which I can accept, but you haven't said that. --

MR. BONACA: I think that a review might be valuable. You know, another area where there are even more similarities is naval applications. I mean I would expect that the naval applications you have layout of the diesel generators, you have layout of equipment and pumps, et cetera, which really parallel very often nuclear power plants. I mean a lot of plant installations.

MR. BARANOWSKY: I was going to suggest that you're raising valid points, that as we go through the presentation, we identify those areas where we're weak on data. And we'll note, if you will, those situations. And we'll, as a takeaway, go back, and if we can't answer it here, see what's going on and why the larger fire database from other industries might or might not be applicable.

But I guess I would make the point that what we're really talking about is whether or not we can reduce the uncertainty in the validation of the models by having better data. And I think on top of that, we would have to add is there a payoff to going and getting more data, and I don't know whether there is or isn't, whether the uncertainty is such that you have a gap in your usability.

MR. NAJAFI: Well, the thing is that always it depends on the quality of the data. Until you get the data and put it in there, you don't know whether it's going to improve your results or not. And it may.

MR. APOSTOLAKIS: Some of your collaborators, like NIST, must have experience with other industries, and some of the International people, and some of your reviewers. The reviewers were not exclusively nuclear people, so did any of those researchers raise the issue and say something about it.

MR. HAMINS: May I try to answer your question? My name is Anthony Hamins. I am at NIST. I'm the leader of the Analysis and Prediction group.

I'm an experimentalist. I'm the sole experimentalist in this group. We did a search of the fire literature in order determine well-documented comprehensive compartment fire test data. It had to be well-documented, because our emphasis on experimental uncertainty and understanding the details. In order to do a comprehensive comparison of models and experiments, we needed to understand the experiments that were undertaken. So we needed extremely good documentation.

We needed something that's not typical in the experimental literature, which is an analysis of uncertainty. Uncertainty has recently been emphasized at a number institutions and international organizations, but in previous years it has not been. So there is much data in the literature that is, I would say, not comprehensive and not well-documented. And that's why NRC has ben funding studies in this experimental area for validation. That's why the international community got together in the ICFMP group to search out and create databases for model validation.

We work with chemical industry. We work with the Navy for example. I'm very familiar with the kinds of experimentation that they're funding.

And we are not aware of any experimental database in the literature that we could use. We selected data that was the appropriate data, and I'll talk a little bit more about that during my presentation.

MR. APOSTOLAKIS: So I take it then that your answer to Professor Banerjee's question is that you are aware of what is happening in the chemical and other industries, but you decided that they were not appropriate or they were not in a form that could be used by us?

MR. HAMINS: That's correct.

MR. KHALIK: Do you have a documentation of this process?

MR. HAMINS: Of the selection process of the experiment?

MR. KHALIK: That's right, the exclusion of data from other industries.

MR. HAMINS: I'm not sure that we have a documented process of that literature. Now we could go through the literature and document which tests were not selected and the reasons for each of the decisions for each of the tests. We could possibly do that, but we have not done that at this point.

MR. BANERJEE: The fire models that you have are generic models I take it, so they're not specific just to the nuclear industry. I was looking through your documents.

MR. HAMINS: Yes.

MR. BANERJEE: So they're validated only with data from the nuclear industry or --

MR. HAMINS: The nuclear industry, NRC has taken a lead role here in validation. In the fire literature, there has been very little comprehensive validation work. This is really a unique comprehensive study. This is the largest validation study that I'm aware of. In my 20 years of fire research, I've never seen a study as comprehensive on validation.

MR. APOSTOLAKIS: But, you know, reading FIVE for example, and I was familiar with it and also with other models, there are various empirical or semi-empirical formulas for the height of the fire, the ceiling and so on. Now when people propose models like that in their general fire literature, how do they convince you for example that the model is valid or is useful. I mean you say that this is a unique study. I understand that it may be unique because of its scope and size, but surely when say Professor Quintiere proposed his model which you're referring to, he's provided some evidence that the model gave reasonable predictions. So how is that process differing from what we are doing here?

MR. HAMINS: Jason, do you want to try –

MR. DREISBACH: Well, that process didn't take a systematic approach sort of like there's a lot of models, say Dr. Quintiere's models for instance, the MOU model for temperature and hot gas layer, there's a lot of other people that have created similar type correlations. They've all used data to provide evidence that their particular correlation is reasonable.

MR. APOSTOLAKIS: So data means, you know, it says, look, this guy did this experiment. I ran my code, and I'm within 20 percent. I mean that kind of data?

MR. DREISBACH: That's not what the typical validation or confidence level is. It's more of a general kind of statement as far as a judgment. This provides reasonable approximation.

MR. APOSTOLAKIS: What's reasonable?

MR. DREISBACH: That's --

MR. APOSTOLAKIS: I mean if they use data --

MR. DREISBACH: That's what we're trying

to answer here. There has been no definition of what reasonable or good predication is in the previous fire literature.

MR. APOSTOLAKIS: But there is a whole -- I mean there is a general fire safety and so on. I can't imagine that a guy proposes a model, and then he says I think it's reasonable. I mean there must be some quantitative evaluation.

MR. PEACOCK: I'll be happy to address that. I'm Rick Peacock from NIST. I've been involved in the development and the use of zone fire models for the last 20 years and am particularly interested in model evaluation. One of the things you see, and you're correct, there is a tremendous number of articles out there of people comparing model x to some set of experiments. If you look at those as a whole, and I have actually collected a couple of slides of these, there's two characteristics of those papers that it comes close to 100 percent, these attributes exist in all the papers. One is that all of the comparisons end up being qualitative. There's quotes like "the model looks good", "the model compares well", "the model predicts acceptably", and the second thing is they're all positive. Rarely is there a negative connotation for these set of comparisons.

So certainly there is a broad literature certainly for the models we developed here at NIST of both NIST as well as others providing evaluation and validation of these models for a wide range of applications from small compartments to multi-story hotel rooms to large atria. And that exists not only just for the models but also for the sub-models as well. All of that stuff is typically documented in the technical reference guides for the models. That's certainly the case for CFAST. That's certainly the case for FDS. What we tried to do here is not duplicate all that effort but focus that effort on being quantitative as much as we could and in focusing on scenarios that were of interest to the nuclear industry. So what that says to me is we don't have to use the entire universe of data, rather we chose the best quality data we can and the ones that best represent the scenarios that we see in nuclear power plants.

MR. APOSTOLAKIS: Do you have -- yes, sir.

MR. JOGLAR: Thanks.

MR. APOSTOLAKIS: Yes, sir.

MR. JOGLAR: If I may --

MR. APOSTOLAKIS: I guess you have to
repeat your name.

MR. JOGLAR: My name is Francisco
Joglar. I work for SAIC. My comment may even go back to your first question is that we also had the challenge that these products will be used for regulatory purposes, and that sometimes ties our hands in suggesting how would regulators use our results. So in a way, we are kind of forced to just report the validation results kind of in an independent way and let regulators decide what to do with that, because in some ways we are kind of -- our hands are tied in telling regulators how they would use these results for their applications.

MR. APOSTOLAKIS: Can you give us an
example where the NRC tied your hands?

MR. NAJAFI: Let me clarify that. What
he is talking about is that the MOU basically it allows us to collect data, analyze data, and present the results of the data. How that it's going to be used in a regulatory framework, is not the job that we can do at this MOU. That's what he means.

MR. APOSTOLAKIS: I understand that.

MR. NAJAFI: But coming back to your
question, that might be slightly different how a

user will use that. That's why I said we'll come back to that one later, and in fact we will hear towards the end of this presentation that one of the projects that Gary Vine talked about is a fire modeling users guide, that something like this will even expand even further into a fire modeling users guide that says how a user can use these color-coded results. I know that we came up with a pseudo-quantitative, but I want to emphasize, I guess, this is the feeling of the entire team that given where we are, this is the best we were all collectively were comfortable to come up with.

MR. APOSTOLAKIS: Well, the reason why you're getting these questions from me -- I can't speak for my colleagues -- is because I read these reports from the user's perspective.

MR. NAJAFI: I understand. I understand.

MR. APOSTOLAKIS: The whole thing -- every time I read a paragraph, I asked myself how would that help me if I were to do a Fire PRA, how would that help me if I had to implement 5048-C and so on and so on. And that's why you get these questions.

MR. NAJAFI: Yes. Those are the first

questions I ask myself. Those are the first questions.

MR. APOSTOLAKIS: And we're a very practical agency here. We do make decisions. I mean --

MR. NAJAFI: And in fact, the first time around, we came up with numbers and ranges, and then when we realized --

MR. APOSTOLAKIS: The follies of your ways.

MR. NAJAFI: No. Because everybody started saying ifs and buts, and they started adding ifs and buts, four pages of ifs and buts. And I said, that's not useful to the user. If you said use plus or minus this much with that if, and if you give them two pages of if and but, that's just as not useful as giving them a graded, what I call a graded, range of shades. So, I mean we'll talk about how --

MR. KHALIK: The comment was made earlier sort of criticizing earlier assessments of models as being qualitative in nature, and the question in my mind is what's the difference between that and the color code that you came up with. It is still qualitative.

MR. NAJAFI: No. I believe it's half qualitative. I believe it's halfway in between. Because we assign a range. These ranges and these numbers have quantitative bases in them. We very clearly have quantitative numerics that is outlined in the appendices that it derives these ranges.

MR. DREISBACH: We don't claim to reduce qualitative judgment. We want to reduce some of the qualitative and judgment aspects of the decisions, so we add some quantitative, but we're not absolutely --

MR. APOSTOLAKIS: I think our discussion and concerns will be better addressed if you actually -- I don't know whether you plan to do this -- walk us through an example in detail. Here is what we had. Here is the test. Here's what we did. Here are the uncertainties. This is how we decided it was yellow plus.

MR. DREISBACH: Presentations along those lines.

MR. NAJAFI: When we get to that putting the results up, I will try to go through one example.

MR. APOSTOLAKIS: That's a very important part. I mean I don't know.

MR. NAJAFI: No, I -- believe me, I under --

MR. BANERJEE: The feeling that I'm getting from the discussion is that let's say the results of an experiment are pretty sensitive to things like initial conditions and scenarios, so they're sort of classically ill-posed problems, which means you don't get sort of a deterministic outcome because small changes in initial conditions can make a big difference in the results. Is that true? In a sense, it's inherently uncertain?

MR. DREISBACH: And that's part of what we're trying to get to.

PARTICIPANT: But come on guys, define the catch rise with yellow pluses. So it's turbulence. Yes.

MR. APOSTOLAKIS: This industry has dealt with severe accidents, and I can't imagine that your problem is more difficult than predicting what happens in a containment when the corium starts moving around. And yet --

MR. BANERJEE: That's science fiction. Right.

MR. APOSTOLAKIS: But yet 1150 came up with some estimates, some uncertainty estimate, they had experts, they had reviews, and their estimate were consistent with the PRA. So it's not like we're dealing with an entirely -- and they were-- in fact that's why I'm saying this, because I remember in the review process, we had a gentleman who was not a nuclear person, he was a fluid mechanician, and he said exactly the same the thing. When I do experiments, I know that some things -- if I change a few things in the inputs, I may have a lot of changes in the output, and you guys are telling me you know what's going on in this big volume and all that. So I mean we have handled it in the past. Okay?

And then in the thermohydraulics area, these CSAU method that systematically walks you through a process that ends up with a statement of uncertainty, correct Hossein? So did you take advantage of these things? I mean did you look at CSAU and see whether what you're doing is consistent? I mean after all, it's an NRC method. Don't ask me more. I will rely on my colleagues here to --

MR. NOURBAKHSH: The scaling methodology for severe accidents. Actually, it's a NUREG. Discusses the process on first of all for each scenario, you define your figure of merits, what are the important at attributes for that scenario, and then that provides you an input to quantifying the scaling distortion, these elements of scaling, and the impact of whether in your experiment there are distortions, and even how you incorporate some of these uncertainties and the separate effect experiments, and then you take --

MR. NAJAFI: I guess I will express the response in two pieces. First, I don't think the problem we have is any simpler than that. It's just as hard. But you're correct. I mean we started with this project with the objective of validation and verification of these codes and how do we characterize this into a probabilistic framework. It was not defined at the early on as the objective of this project.

MR. APOSTOLAKIS: Did you look at CSAU at all?

MR. NAJAFI: We looked at a methodology that was developed for the fire modeling uncertainty by the NRC, Nathan Su, and I mean we looked at -- Francisco can talk about that a little bit maybe -- but we did look at alternatives. We looked at options. I don't know specifically about SCAU but methods out there that have been used to deal with the uncertainty and physical phenomena. And that is not or was not part of the scope of this work.

MR. APOSTOLAKIS: Because you followed the ASTM standard.

MR. NAJAFI: Yes.

MR. DREISBACH: That's what we followed. That's the methodology we followed --

MR. APOSTOLAKIS: But I mean --

MR. DREISBACH: -- because it's written for evaluating the predictive capabilities of models, fire models specifically. So we determined that was a way we needed to approach the product, because there is a standard out there.

MR. APOSTOLAKIS: I would expect though that when you selected these, you would also look at other methods that have been used by our agency and see whether, you know, some sort of hybrid would have been better or -- anyway, I think we are spending too much time on this and let's move on.

MR. NAJAFI: The project team, basically, to cover, we see through the next slide, there are several expertise or critical scale area that we considered very crucial to this. One is the nuclear power plant fire scenarios. This is very important understanding what these critical issues are. We'll talk about that. I know you guys need to know. EPRI and NRC, through basically fire modeling guide, the training, and the SDP process, we've had experience with what these scenarios are. And for us, we had fire science and model development in NIST, EDF, EPRI and NRC to ensure that we understand well the strength and weaknesses of these models and where and how these map or match into the fire scenarios and attributes that we're interested in, and we had experimentalists to ensure that we understand the appropriateness of these experiments towards the scenarios at NIST that they brought to this team. We had an independent review of this project by Professor Quintiere and Dr. Beyer and Phil DiNenno primarily for the fact that these people were key, some of the individuals involved in those correlations went into our hand calculations.

MR. APOSTOLAKIS: Now are you coming back to the scenario business later or?

MR. DREISBACH: In the next few slides.

MR. NAJAFI: In the next few slides.

MR. APOSTOLAKIS: Said?

MR. KHALIK: Well, I was going to ask about that. Presumably you selected these scenarios to capture what you have referred to as the unique aspects of fires in nuclear facilities?

MR. NAJAFI: Yes.

MR. KHALIK: And you will go through that process of how these scenarios particularly capture those unique aspects?

MR. NAJAFI: Yes, sir.

MR. KHALIK: Okay.

MR. NAJAFI: The next couple of slides is basically where we talk about the public comments. We have received extensive comments over a period of 60 days, and we’ve – the document you have reflects that --

MR. APOSTOLAKIS: Yes. We've read that. You responded to each one of them. Let's move on.

MR. DREISBACH: Okay.

MR. APOSTOLAKIS: Well, I'm trying to get -- you know, there is a lot of discussion and things. I don't want to --

MR. NAJAFI: Okay. And then the next one is basically the presentations to come.

MR. DREISBACH: So now I'm going to sort of try and go through our technical approach. We've already obviously talked about quite a bit of what we went through, but I just wanted to put up definitions of verification and validation. When we were here in front of the ACRS last year, this was a question we were asked, "What is your definition of verification and validation", so I wanted to make sure we revisited this to get everybody on the same page here.

So our approach to verification is making sure or understanding whether the model was built correctly, basically the mathematics and numerics of the code. And then validation was was the correct model built, basically are the physics of the model representative of what we're trying to answer or what the solution is.

And then one of the key things that the NRC wanted to make sure this process was about was the transparency. So after this process is over, all of the data that we used, all the model inputs that we used, all the model runs that we provided, the inputs to the models, they will all be in the public domain so that anybody who wanted to rain event visit or try and recreate this process themselves, they will be able to do that. And since the experimental data will be available, anybody who wants to use a different model and go through the same process or even a different process, all that stuff will be available. We'll make that available in the public domain.

So that leads us to what do we need to do to do verification and validation. And so we asked ourselves these questions to get at a process that we could use. Obviously, the first one up in question so far this morning, "What scenarios are of concern, what are the important measurement and parameters of those scenarios that we're concerned about." Then we wanted -- to provide validation, we have to have some sort of experimental database. And so what experiments have been performed that will address these kinds of concerns. And then we needed to see what models are out there that we can use to do these kind of things. And how do we evaluate those models. That's what we're going to step through here. And sort of the user aspects, "How do we know if a model is valid for a specific circumstance." That was the basis of our approach to going through this.

And as we've mentioned already, this ASTME 1355 provides us with an approach to step through those questions. It's a standard approach. It's an international standard. Something that's important to us -- we didn't want to reinvent a wheel. We could potentially have used other methods. This is the one we chose because it specifically catered to evaluating the predictive capabilities of fire models.

It's a process obviously, so what we've already established is the hard part is what is the degree of accuracy required. What does the regulator need to be confident in an analysis that uses one of these models. So that was part of what we had to establish in this process to be able to use what our results were in a wider scope than just the experiment to be considered. So this standard suggests an approach of a specific evaluation technique, many evaluation techniques actually, but it doesn't require one over another. So there is some flexibility as far as some of the things that we used that is in the standard.

Now I'm going to leave it up to Bijan again to talk about more specifically the scenarios and the measures and parameters.

MR. NAJAFI: Okay. This is the part of the presentation that I guess I'll hope will answer your question about what are the nuclear power plant scenarios that we talk about. I guess one of the first steps to the validation is for us to determine any, and this is where the need comes in --these nuclear power plant fire scenarios were first developed as a library by EPRI in 2000, and published in a document in 2001. The process for selection, and this was basically the intent at the time, was to generate a document as a guide, that if somebody wants to do fire modeling in a nuclear power plant, basically how do they go about to do that. And that process had basically almost like a guide or manual that says you do this first, and do this, do this, do this, do this, do this.

In order to develop that, you have to understand what are the questions that people may ask, what do they want to use it for, and that the first need was to develop a library of fire scenarios that they will likely be analyzing. So we did this, we went first, looked at the result of the IPEEE that was done during the late 80's and early 90's. That was probably the most – for the nuclear, the most widely used risk and fire modeling on an industry-wide basis, meaning the people went around and analyzed their plant and the fire scenarios in their plant.

So we created, looked, reviewed almost a number of about 70 IPEEEs to get input from their fire scenarios. Then we surveyed the industry. We sent a survey to the industry and said, "Tell me what have you used fire modeling for outside of IPEEE for some exemption, for whatever". So we got some answers from them. Then we surveyed the NRC NRR, and we sent some questions to them and said how many submittals have you received from the industry or somebody based on fire modeling, and what was the example of it. So we took all of that data and put it into information and created a set of what we call library of nuclear power plant fire scenarios.

Now, how did we define these? We defined these on basically --

MR. APOSTOLAKIS: Before you move on, I assume you looked at the actual Fire PRAs that have been done for some plants, not just the IPEEEs?

MR. NAJAFI: Yes. We looked at older ones.

MR. APOSTOLAKIS: There is a statement in the first volume that intrigues me and is related to a scenario. I can read it to you. "The scope of this V&V study is limited to the capabilities of the selected fire models. There are potential fire scenarios in NPP fire modeling applications that do not fall within the capabilities of these models and, therefore, are not covered by this V&V study," and I don't know what these models, what these scenarios are. You don't tell me.

MR. DREISBACH: I can --

MR. APOSTOLAKIS: Do you tell me somewhere else?

MR. DREISBACH: Yes. Yes. Yes.

MR. APOSTOLAKIS: So there are some scenarios for which none of these models is helpful?

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: And where can I find those scenarios?

MR. DREISBACH: 6850, EPRI 1011989. Those I'll give you an example. One example high energy arching fault -- is that how the high energy arcing fault in a 66 KV switchgear generates and propagates the fire. We currently cannot model that. Correct me if I'm wrong with any of these models.

MR. APOSTOLAKIS: Would it have hurt to --

MR. NAJAFI: Name -- make a list here?

MR. APOSTOLAKIS: Yes, to help --

MR. NAJAFI: Okay. No. It would not hurt.

MR. APOSTOLAKIS: Since it's so easy for you to answer it, can you send an email to Hossein later, at least guide us where we can go and find those?

MR. NAJAFI: Yes.

MR. APOSTOLAKIS: I'm not asking you to do a lot of work, just, you know, off the top of your head. Obviously, you know.

MR. NAJAFI: Yes. There's a list of half a dozen to a dozen.

MR. APOSTOLAKIS: Okay. So you'll provide these scenarios to us?

MR. NAJAFI: Yes.

MR. KHALIK: Also, presumably there is a range of non-dimensional parameters or attributes. You classify different experiments with the ranges of these parameters which they cover. And the question is, do you have the ranges of these attributes in which nuclear power plant fires are expected to fall?

MR. NAJAFI: In some cases, yes, we do. In fact we generated that information as an input to those people who conducted the validation. I'll give you an example. When we defined a fire scenario and we said for example for a control room, there are fire scenarios in the control room, and the attributes in a control room that we're interested is these: First, fire propagation from one panel to the next we know you can't calculate. That's one of a half a dozen I told you.

The other one is the smoke generation and migration and the timing of it we're interested. Yes, these models can deal with that. And as part of that definition, we said, by the way, the size of the control room in this industry vary from small to medium to large if it matters to your V&V. Some of those ranges of parameters, I make a distinction, because we talk about some other similar sounding terms, but ranges of parameters we collected. Some were appropriate and when used in the V&V, some didn't matter. Some didn't matter.

For example, the size of a room in some cases may not have mattered in the accuracy or predictive capability of the code. It obviously mattered in the answer but not the predictive capability of the code.

But we did define those ranges. We did --

MR. KHALIK: But I guess I'm still lost in a sense that I'm trying to define the physical attributes and the parameter ranges that I would say this is the range of parameters in which nuclear power plant fire would fall, these are the ranges of geometries that I'm interested in, these are the ranges of boundary conditions that I would be interested in. And I need to start from something like that to be able to make the connection to these are the scenarios that we looked at, and these are the experiments that we think match the physical geometry, boundary conditions and the parameter ranges that we're interested in, and I can't find it in the report.

MR. NAJAFI: In the slides. Oh, in the report?

MR. KHALIK: Correct.

MR. NAJAFI: Okay.

MR. DREISBACH: You're looking for what's actually out there, the ranges of compartment sizes that are --

MR. KHALIK: I'm looking for the logic of the process.

MR. DREISBACH: Okay.

MR. KHALIK: I mean you may have followed a rigid validation and verification process spelled out in some standard, but there have got to be some underlying logic. This is the problem I'm interested in. These are the ranges of geometries that I'm interested in. These are the ranges of boundary conditions that I'm interested in. These are the ranges of parameters that I'm interested in. And these are the experiments, and the experiments actually match the geometries, match the boundary conditions, match the parameter ranges. I can't find that connection.

MR. NAJAFI: I can only say that that was -- I mean what you're saying makes logical sense to me, and that was the intent of our process. If it does not come across, we have to go back. That was the exact objective of developing these scenarios but --

MR. DREISBACH: We provided a methodology for a user to determine the range of their parameters relative to the range of the parameters that we considered. That's the step that we took.

MR. APOSTOLAKIS: Where is that, because I have a similar related --

MR. DREISBACH: That is where we describe the non-dimensional parameters. We characterize that process as something that the user should go through to evaluate his or her particular fire scenario in order to determine the applicability of our report to their scenario.

MR. APOSTOLAKIS: But the way I understood -- maybe I didn't read that part, but the statements that I read, I got the impression that you wanted the user to go back and look at the experiments that you guys have used and make sure that his or her parameter ranges are consistent with those, which I thought was a big job.

MR. JOGLAR: This is Francisco Joglar again. And I think that's not our intent. We were operating under the challenge that there are some nuclear power plant fire scenarios, there are experiments, and they are models, and none of them fit perfectly within each other. They are experiments that will never match identical nuclear power plant fire scenarios, not all of them. And there are models with limitations that will not be able to calculate every single aspect of the experiments or the fire scenarios. So that's the challenge we operate. Therefore, all we could -- I guess our approach was let's take these experiments and characterize it with these non-dimensional parameters so that people, when they're applying it in their plants, they will be able to calculate that number for themselves and see if it fits within the experiments we have. So they don't have to read all these experiments. They have to go to their plant and see if the geometry, their parameters will fit within the parameter for which we are providing validation which is limited by the experiment. And then in that way, they will be able to use the --

MR. APOSTOLAKIS: Are you going to talk about it today?

MR. NAJAFI: Yes. That's why we --

MR. BANERJEE: So these non-dimensional parameters -- sorry -- are known?

MR. NAJAFI: Yes. That's the approach we took. They's why we talk about summary. We say now that we found these charts -- that's when I told you at the end we say we hope how -- a user comes in with a scenario, and he knows the characteristics of his scenario, the size of the room, the size of the fire and everything, now we gave him this non-dimensional some set of rules that says check it against thee rules. This is the first frontal. If you pass through this first hoop, then we validation for you.

MR. BANERJEE: This is a very important

point, so I hope you go over in some detail how you arrived at these non-dimensional --

MR. NAJAFI: Those non-dimensional parameters --

MR. BANERJEE: -- and what the science base for them --

MR. NAJAFI: Yes. I will leave it to the statisticians and theoreticians that you don't –

MR. BANERJEE: We would really like to know the science base behind that.

MR. NAJAFI: Yes. Very quickly, these non dimensional parameters have been developed for fire applications, so this is not something we developed. They are out of the literature for fire applications.

MR. BANERJEE: But did you validate that these non-dimensional parameters actually apply or that they're not simply things in the literature? I mean there are lots of correlations and things in the literature which may or may not apply. It depends on ranges of parameters and all sorts of things. I can name lots of them in fluid mechanics and heat transfer where -- you know, there are things in the literature, but it doesn't mean that they actually work.

MR. NAJAFI: We'll talk about --

MR. BANERJEE: Oh, you're going to talk about that. We would like to have a fairly clear picture.

MR. NAJAFI: This is actually something we developed internally. We had --

MR. BANERJEE: It's very important I think.

MR. DREISBACH: Further on, we'll get to it.

MR. APOSTOLAKIS: I suggest that you guys -- I mean you are experienced presenters -- you skip a lot of the process stuff --

MR. DREISBACH: Okay.

MR. BANERJEE: Yes.

MR. APOSTOLAKIS: -- and go to the to the technical technical stuff as soon as you can, because obviously that's the interest of the subcommittee.

MR. NAJAFI: So then I'll leave it up to you guys to see if it's clear about how do we derive the fire scenarios and if you want to know anything about the fire scenarios. Because the next two slides that you see is basically is going to give you a summary that we came up with as many as maybe a dozen or 16 fire scenarios for a nuclear power plant. I'll give you one or two examples of them. And that defines first the scenario, and then what I call attributes of the scenario, meaning what parameters in that scenario are critical and objective.

One example is a control room fire scenario. What we're interested in is a fire that can propagate first inside from cabinet to cabinet. And second, the attributes we're interested in is the amount migration and the timing of the smoke that it can generate.

Another example is a fire inside of the cable room or a cable tunnel. That fire may start inside of a cable as a self-ignited cable fire or may be triggered by a secondary fire. The mechanism there more of a generated condition is more of a flame spread, fire propagating through one cable tray along its horizontal rate or through cable tray stacks. That's the second scenario.

Another example is a large scenario in a turbine building that may involve large oil fires that may generate hot gases and smoke propagating through grated flooring through multiple layers. And the issue there is that how the smoke and hot gases move from room to room. So through this process, we generated switchgear rooms. These are the scenarios, these are the issues, these are what we're interested in.

In small enclosures, when you have a source and a target, all we're interested in is plume temperature, because in many locations in a nuclear power plant source and target happen to be in very close proximity. So all you have to know is a plume temperature correlation, and you're done.

And so we defined all of these, and we made a list of a dozen or 16 scenarios with as many as 12 attributes that says pressure, temperature, smoke density and things that we're interested in with different scenarios. That's how these were derived, and this basically forms for us the need, go validate these. That's why we didn't calculate, for example, egress time. We did calculate plume temperature.

MR. BANERJEE: Do you have a slide with the scenarios and the parameters of interest?

MR. DREISBACH: That's what these --

MR. NAJAFI: These are basically some summarized version of it. We don't have one slide that makes a list of all the 16. They are basically in Sections 2.3 and 2.4, I believe, of the Volume I.

MR. JOGLAR: This is Francisco again. But these slides -- these bullets are those: room temperature, flame height, plume and ceiling deck temperature. And as we move through the slide, you would see oxygen and smoke concentration, room pressure. Those are the ones that we are providing validation, those parameters.

MR. APOSTOLAKIS: So you said in a control room fire, I'm interested in knowing the oxygen and smoke concentration?

MR. NAJAFI: Yes.

MR. APOSTOLAKIS: And then you ask yourselves which models attempt or claim to predict this?

MR. NAJAFI: What is the capability of each model in predicting that. We don't say --

MR. APOSTOLAKIS: Not all of them.

MR. NAJAFI: We're not trying to say which one is better, which one is worse, we're saying that --

MR. APOSTOLAKIS: Some of them may not even do it at all?

MR. NAJAFI: Exactly. That's why the NA is in the boxes.

MR. BANERJEE: But you're also interested in the propagation of the fire from panel to panel there?

MR. NAJAFI: Where these -- remember what George asked, -- where these models are applicable, because the panel to panel is one of the half dozen or dozen that I told --

MR. BANERJEE: That you cannot calculate?

MR. NAJAFI: You cannot do that. Another example is the problem in a control room inside of the control board, the horseshoe, how far and how fast the fire propagates, that's the a giant metal box with all kinds of cables running around. And how and fast and how far the fire propagates, we don't do these with these computational fire models. That's outside their capability.

Again, go to the other document. We provide some empirical model to deal with that, for those that we could. Yes?

MR. BANERJEE: But though in these scenarios, there are some aspects which are handled by your computational models and some you give some empirical guidance?

MR. NAJAFI: That is correct, but here

in the list, you only see the computational one. He is correct that we need to get the empirical one embedded somewhere that says --

MR. BANERJEE: Right.

MR. NAJAFI: -- these are the ones that are nuclear fire scenarios that we didn't address here, it's addressed in some other document, go look there.

MR. JOGLAR: And empirical models are, we think, the Fire PRA risk framework, so that's why they are in that other document.

MR. DREISBACH: Okay. So moving on. I'm going to skip through these next two that describe the experiments a little bit, because we have another presentation to talk about that. And we've talked a little bit about what they are and where they came from.

MR. APOSTOLAKIS: Good.

MR. DREISBACH: So I'll just put this slide up to show you the specifics of the models that we selected.

MR. APOSTOLAKIS: I think 16 is interesting. I mean you -- yes.

MR. DREISBACH: Okay. So here’s – I put schematics of the experiments that we considered and how they relate to our overall scenarios. This slide is -- these individual experiments and these diagrams are going to be coming up later when we talk more about the --

MR. APOSTOLAKIS: Just tell us about the scale here.

MR. DREISBACH: Okay. So the turbine hall, the one on the upper right, that height of about 22 meters or 20 meters; the FN/SNL data, that's about 6 meters, 5-1/2 to 6 meters; the pump room is about 5-1/2 meters; the ICFMP 3, the one on the lower left, I think that's 3-1/2 or 4 meters; and the NBS multi-compartment, that's 2-1/2 meters. It's basically the normal room height kind of thing.

MR. BANERJEE: And these experiments were done in full scale or?

MR. DREISBACH: Yes.

MR. BANERJEE: With devices of mocking up these dimensions?

MR. DREISBACH: Yes. Yes. And the fire sizes ranged from, I think, on the order of 100 kilowatts all the way up to 4 megawatts, something like that, depending on the size and the specific experiment that we were looking at. But the details of these experiments will be talked about by Anthony in the next presentation.

MR. NAJAFI: And this is the link that you were talking about, our scenarios and the experiment. There's the kind of link you -- I guess someone --

MR. DREISBACH: Very generally obviously, because we don't have very specific representation necessarily. It's not like we ran tests in a turbine hall or anything like that but --

MR. BONACA: Although these geometries are pretty representative actually of all power plants.

MR. DREISBACH: Right.

MR. BONACA: Especially the switchgear room. I mean this is typical.

MR. DREISBACH: Right. That's what we were trying to do when we found the test series that we evaluated. So here's the models that we selected specifically. We have NUREG-1805 which has been presented to the ACRS in the past, the fire dynamic schools, the five model, and those are what we call hand calculations of engineering calculation models, libraries of models. CFAST and MAGIC are two-zone type models and fire dynamic simulator. That's a CFD model that used LES. And down on the bottom we show sort of the varying complexities. A you go down the list, you increase the complexity of the model. Now --

MR. APOSTOLAKIS: Since we have the NIST gentleman here, when you developed say the FDS or CFAST, did you have any particular industries in mind, any particular applications, or were they just codes that addressed generic issues that most people would face?

MR. McGRATTAN: Yes, general purpose fires in a wide range --

MR. APOSTOLAKIS: Please identify yourself.

MR. McGRATTAN: I'm sorry. My name is Kevin McGrattan, and I'm the developer of FDS. And FDS was developed for a wide range of, it started with, industrial scale fire scenarios but has soon moved to residential scale fires.

MR. KHALIK: And as a part of that development, was there any validation work? In other words, after you developed this code, have you compared the code predictions against data or other models?

MR. McGRATTAN: Oh, absolutely. All along the way these models have been compared with data. In fact, some of the experiments that are discussed today were used previously in validation efforts. The trouble we had was when the NRC asked us about the validation work, we said, okay, here's a paper we wrote five years ago showing FDS compared with say these compartment experiments done 20 years ago. So is that the current version of the model? We said, no.

So what we're doing now, and this is why we're emphasizing comprehensive, is we have to go back, look at all the validation work that we've done in the past, use current versions of the model, document it more adequately, follow the procedures in ASTM 1355. In the past, I hate to say it, we were a bit informal and casual the way we did our validation work. We developed some new routine. We got some test data. We compared it. We published a paper. In the end, we had a long list of publications, but we had no comprehensive document, like the one we're talking about today, to show someone here's how the model works today, not how it worked ten years ago. Here's how it actually works today.

MR. KHALIK: But the implication is that this model is an evolution, you know, that you did this 20 years ago, but the model as it is now, is significantly different than what it was then. Now evolution will continue, so what do you expect to happen five years from now?

MR. McGRATTAN: FDS, the field model, the CFD model is evolving. We continue to do research in fire, and we continue and improve FDS. CFAST, the zone model, is what you would call in a maintenance stage. Most of the development work is completed except for special purpose functions that will be added from time to time depending on the application. But CFAST is generally in a maintenance mode now but FDS is continuing to evolve.

MR. JOGLAR: This is Francisco. To address your question maybe in a more programmatic manner, that's why our effort here is to come up with a validation and verification method that can be reproduced later if things change. So we have specific steps and specific ways to do it so that a new version comes or a new model comes, then it can be reproduced.

MR. KHALIK: But from a user's perspective, based on the outcome of this process, and the recommendations, albeit in color code, would that be tied to specific version of the code as of a specific date?

MR. McGRATTAN: Yes. Presently, it says clearly in these documents which version of the code was used. And if it were to be used in the future, we would ask that those people use the present version of the code unless we demonstrate that some future version, some improved version of the code satisfies all the requirements that we've put for this particular application.

So in other words, if I come out with a new version of FDS two years from now, I'm going to rerun every single case that I've rerun here, produce essentially the same document that you have before you before we release that new version. So this is the basis or the starting point of a process, a more formal process that we're going to use to maintain our models.

Like I said before, in the past, because we were more in a research framework, we were very casual about how we did maintenance. We're now formalizing the process, and this is the first step.

MR. NAJAFI: And I should also add that -- I mean other than FDS, the other codes, particularly the hand calculations have been around in the SFE handbooks for years, and those are pretty much stable. And you heard about CFAST. And I believe MAGIC is in a similar situation. So for a majority of these -- I mean these are relatively stable tools. I mean FDS may be unique in that sense, but the rest of them are not.

MR. PEACOCK: Rick Peacock at NIST. Yes, and I should also mention that some of these experiments we have indeed have comparisons with versions of CFAST, in my case, for the last 15 years. And one of the heartening things is that the answers don't change that much, that it is very small changes in the models that we're seeing as they evolve because they're mature products. So even if I do end up five years from now rerunning this, I don't expect the answers to be significantly from what we found today.

MR. BANERJEE: Let me ask you a question. You've got a hierarchy of models here of increasing complexity, as you said, as you go down. At some point, you will, I suppose, define predictive capability. And when you do that, it would mean, I suppose, that the predictive capability is increasing as you go down. Is that --

MR. DREISBACH: Well, that comes out as our results more or less. We sort of evaluate the models, and as you increase complexity, the question is, the hypothesis is --

MR. BANERJEE: But does it?

MR. DREISBACH: -- do the predictive capabilities improve and we --

MR. BANERJEE: What have you found?

MR. DREISBACH: We found that is indeed the case, and it's due to a variety of reasons and the degree between the levels of complexity is also different when you go from one to the next. For instance, when you go from hand calculations to zone models, your capabilities increase, I won't say significantly, but there is improvement, and it's marked. And that's due to reducing assumptions and limitations of the hand calculations when you go to the zone models. but when you go from the zone models to the FDS, you see some improvement of the capabilities but not as significant a change as from the hand calculations to the zone models.

MR. BANERJEE: In fact, I mean it seems to me that your two-zone models, at least from the results you're presenting, are as good as FDS. I mean it's in different ways but --

MR. DREISBACH: One of the things that we say in addition to that particular point is sometimes it's going to depend on what you're actually comparing against.

MR. BANERJEE: That's the –.

MR. DREISBACH: And the scenarios that we've used are very much appropriate for the zone model type of calculation because you get a fire that produces a very, we see, distinct two-zone kind of condition in a compartment, but there are also other considerations that a user has to take into account as far as his specific scenario, and we do make that point in the conclusions part about the complexity of your particular scenario and how that should enter into your decision making as far as what model you use.

MR. BONACA: It seems to me also one thing that seems to me when I look at the table at the end of the results, the number of parameters that you can estimate or calculate is also the parameter of importance it seems to me. What I mean is that I look at MAGIC and practically on every parameter that you have listed, you can produce a result.

MR. DREISBACH: Right.

MR. BONACA: And most of them -- well, many of them are green, and some of them are yellow.

MR. DREISBACH: Yes.

MR. BONACA: You know, so when I look at that versus say the T, that doesn't give me anything practically except the three or four parameters.

MR. DREISBACH: There are, and we try to make this point in the conclusions, each specific type of model has its application, and it depends on the specific scenario and the information that you want to provide.

MR. BONACA: Yes, but with the spreadsheets, I don't get that many parameters. I get two or three. I mean that's all I get.

MR. JOGLAR: This is Francisco. I am a fire model user. I use it for plant applications. And it's true what you're seeing in that table, the capabilities of predicting some of the things are not there. However, the importance of these spreadsheets is huge, because some of these are very important: plume, hot gas layer, flame height. And when you go and do Fire PRAs, there are numerous calculations that you have to do for every room. And these things are very, very helpful. So I don't want that the amount of capabilities that are listed there demean the importance of these tools for nuclear applications.

MR. BONACA: No. I don't dismiss that. But it seems to me that with the spreadsheets, from reading the material, that so much more is left to the judgment of a fire expert than with the other method that seem to calculate some parameters that I can depend on.

MR. JOGLAR: Yes. And it's part of our, I guess, the profession to determine when you have to go to the other to calculate things that you need for a specific fire scenario. So when you go in applications, you must determine if you need to go to a zone model or a field model to be able to get the answer on the inside unit.

MR. DREISBACH: We can talk about some of these things later one. I've just got a couple more slides.

MR. APOSTOLAKIS: Yes. You're getting now to the validation method.

MR. DREISBACH: Right.

MR. APOSTOLAKIS: So let's take a break at this point. Okay?

MR. DREISBACH: That's fine.

MR. APOSTOLAKIS: So we'll be back -- let's see, when -- 10:25.

(Whereupon, the forgoing matter went off the record at 10:10 a.m. and went back on the record at 10:29 a.m.)

MR. APOSTOLAKIS: Okay. We're back in session. Please continue.

MR. BONACA: Just for the record, one observation that I made prior to the break, I asked questions regarding the two approaches which are spreadsheets approaches, and then I made a comment that you don't get much from those, you have only a few parameters coming out. And the answer came that said, but those parameters are one of the most important. You know?

And my suggestion is that for the sake of the report, I think these observations are important in the sections. I think if you have qualitative observations of that nature, they should be there. Because I mean this report doesn't only interest the fire community. I think it interests a larger community including the PRA community or engineering community that needs this kind of information to understand why we're comparing side by side.

When I look at the table 3-1 and the results, I become very critical of the spreadsheets, and the comments, in fact, of the text are pretty critical, too. When I hear a comment like that about "but these are the most important parameters and the spreadsheets can't calculate those", those are insights that should be provided in the results. And I think there are others that could be provided there. Just a comment for the record.

MR. DREISBACH: Okay.

MR. APOSTOLAKIS: Are you skipping --

MR. DREISBACH: Yes, because those two slides are going to be talked about more extensively with the next presentation, so I'll just skip over those for the time being.

MR. APOSTOLAKIS: So you're going to slide 20.

MR. DREISBACH: Twenty. Talk a little bit. We've talked about this briefly already, using the results. So what we realize is the scenarios can be described in terms of the physical environment and the phenomenon of interest. That's an important thing that we brought down with us. So what we attempted to do was translate the characteristics and phenomenon from the real scenarios into the common language. that's where we get the normalized or non-dimensional parameters. And then we compare those parameters. We recommend the user compare those non-dimensionalized parameters from his scenario with the ones that we calculate for the experimental scenarios.

And I show here two of the examples of our non-dimensionalized or normalized parameters. The one on the left, Q^d-star is a characteristic heat release rate or energy release form a fire. That's normalized by size, diameter. The one on the right up at the top is a ventilation parameter, and it describes or characterizes a burning rate or the availability of oxygen to sustain a fire.

MR. BANERJEE: Which one is this?

MR. DREISBACH: The one on the right. The phi. And in the lower one, the D-star is another characteristic energy release rate that's used to normalize a height of a room or a more physical characteristic of the room.

MR. BANERJEE: What is "r" there?

MR. DREISBACH: R is the stoichiometric ration. These are just examples. There are a few more normalized parameters that we have, and they're described further on. And we can talk about --

MR. BANERJEE: Well, how do you estimate Q dot?

MR. DREISBACH: Q dot is measured by the experiment.

MR. BANERJEE: But Q dot is the heat

release rate per unit volume, per unit time?

MR. DREISBACH: Kilowatts.

MR. BANERJEE: Oh, kilowatts. Just total.

MR. DREISBACH: For watts.

MR. BANERJEE: Total heat release?

MR. DREISBACH: Exactly.

MR. BANERJEE: So how do you estimate that a priori? I mean if these are non-dimensional groups that you will use to classify scenarios?

MR. DREISBACH: Yes.

MR. BANERJEE: Q dot is a dependent variable?

MR. JOGLAR: This is Francisco. That is depending on your specific scenario, and there are guidance like the Fire PRA guidance that recommends some heat release rate values to use when you're analyzing scenarios. So that's an input for a specific application.

MR. BANERJEE: But imagine you're using a code like FDS or whatever, Q dot is part of the thing that you calculate?

MR. DREISBACH: No.

MR. BANERJEE: It's an input?

MR. DREISBACH: It's an input.

MR. APOSTOLAKIS: Don't you have --

MR. BANERJEE: Don't you have combustion a priori.

MR. APOSTOLAKIS: Yes.

MR. McGRATTAN: Let me address that.

MR. BANERJEE: That's strange.

MR. APOSTOLAKIS: Speak to the microphone.

MR. McGRATTAN: This is Kevin McGrattan. FDS is used for those types of applications. For example, engineers could use FDS to predict the burning of this room. And it will predict the spread of the fire and so forth. But those types of applications were not included in this V&V exercise. So in this V&V exercise, all of the models used a specified heat release rate. That's not to say that the models can't make a prediction. FDS does make predictions of heat release rate, but in these exercises, all of the heat release rates were specified.

MR. BANERJEE: So what you do as input then is the heat release rate and the radius of the fire or whatever?

MR. McGRATTAN: Correct.

MR. BANERJEE: So these are input parameters?

MR. McGRATTAN: These are input

parameters, yes.

MR. BANERJEE: Then they're not part of --

MR. DREISBACH: In this analysis, that's what --

MR. BANERJEE: So all you really do is the fluid dynamics part of it.

MR. McGRATTAN: That's right. Mass and heat transfer throughout the compartment, transport. Primarily transport.

MR. BANERJEE: So it's the fluid phase?

MR. McGRATTAN: Yes.

MR. BANERJEE: The propagation of the fire itself is not taken care of?

MR. McGRATTAN: Right.

MR. BANERJEE: So if I go one step back, somebody's interested in a fire resulting from spilling of 100 gallons of diesel oil in some compartment, how would they go to step one in your model?

MR. DREISBACH: They need to estimate the heat release rate of that spill.

MR. BANERJEE: How would they know that?

MR. NAJAFI: This is Bijan Najafi. In one of the later slides, in the summary of the results, we'll talk about the process of fire modeling, steps of fire modeling and how this fits into that. What comes into these models is a process of selecting and characterizing your fire scenario. Part of characterizing the fire scenario is characterizing the ignition source, and that requires characterizing the type, whether it's an electrical or oil or gas; the location of it, whether it's on the floor, elevated; the intensity of it, what is the kilowatt; and the duration of it, whether it's a small fire, a fast-burning fire. The reason we do it that way outside of the code, because in the nuclear power industry, we have a series of tests and experiments that we use to rely on to characterize a fire source. So we have done stuff for electrical panel, and we characterize those as an electrical fire, based on that.

MR. BANERJEE: Excuse me. I'm missing something there. The intensity must depend on, for example, the fluid. Clearly, if you have a chimney, the intensity is different from where you don't have a chimney. So it's a fully coupled problem to the fluid dynamics. I don't understand how you separate them.

MR. NAJAFI: No. The intensity that we put into the code --

MR. BANERJEE: It's arbitrary. It should

be a function of the fluid dynamics.

MR. NAJAFI: But it does change. I mean Kevin can explain. We put in an intensity --

MR. BANERJEE: Excuse me. I'm asking a straightforward question. I know you put in an intensity. I'm saying that intensity is a function of the fluid mechanics, so how do you decouple them? It's a straightforward question.

MR. McGRATTAN: It is a straightforward question.

MR. BANERJEE: And it needs a straightforward answer.

MR. McGRATTAN: And a lot of this gets into how these models are used in practice. And I can tell you my experience with fire protection engineering community who use FDS, they basically use it in two different ways. One, they use it for a design problem, in which case the AHJ, that might be the fire marshal, he simply says, here's my shopping mall; we have a little McDonald's over here in this area; I'm going to assume that that McDonald's flashes over, that it becomes a fully engulfing fire; I'm going to estimate that that kind of fire is going to produce 20 megawatts of heat; you tell me when the sprinkler is going to activate somewhere down the hall. That's a design consideration. Okay? The engineer is not being asked to predict how that fire starts in the McDonald's or how it spreads in the McDonald's. He's really interested in knowing, worst-case scenario, that whole McDonald's is lost, can I get the people out of the shopping mall. So that is a typical use of the model for design. And in that case, the FDS user would simply dial in the 20 megawatts of energy. He wouldn't go to the effort of trying to predict exactly how that fire would spread.

MR. APOSTOLAKIS: You're talking nuclear compartments though. I mean you don't assume that the whole thing is --

MR. McGRATTAN: Of course, this is just an example. This is just an example.

MR. BANERJEE: But, in general, the intensity of your fire depends on oxygen delivery. That's also a factor that enters into it.

MR. McGRATTAN: Right. But in that design application, the engineer is being told by the authority: "I think the heat release rate from the fire is going to be this." And that is what Francisco was saying. Oftentimes, in nuclear design, the engineer is told that this cabinet or this pump is going to produce x amount of kilowatts or megawatts.

A lot of times that number comes from an experiment. It's difficult for a fire model to predict, to outright predict what the heat release rate is going to be from a burning piece of equipment or the oil spill that you referred to.

MR. BANERJEE: Well, presumably --

MR. McGRATTAN: So you often get that number from an experiment, and then you put it into the fire model. And the fire model is only expected to do the smoke and heat transport.

MR. BANERJEE: But the experiment, whether it's done in a small room or a large room, whatever, you know, the shape and size, the turbulence, I mean it's very dependent on all these factors. And we know that for example -- I know more about explosions -- but the propagation between compartments, for example, if you go through a pipe, you change the diameter of the pipe, you get a different heat release rate.

MR. McGRATTAN: Exactly.

MR. BANERJEE: Completely.

MR. McGRATTAN: Exactly.

MR. BANERJEE: Due to the turbulence. So how is it that this experiment gives you this value, then becomes enshrined in this way and serves as an input to this model. I mean then what are we talking about? There's a huge uncertainty in that experiment itself.

MR. McGRATTAN: Right. And that's a good lead in for Anthony Hamins' talk, because he's going to talk about how the uncertainty in the heat release rate propagates through the model. Because oftentimes when you're talking about the uncertainty in the model predictions, the key uncertainty is not the model itself but rather the input data. Does that cabinet produce one megawatt or two megawatts. That often becomes a much bigger issue than the model itself.

MR. BANERJEE: But there's an interaction between the model and the heat release rate.

MR. McGRATTAN: Right.

MR. JOGLAR: This is Francisco. Something that has not been mentioned is heat release rate in a practical application we put it as an input. Zone models and field models will, however, use that input and maybe modify it, depending on the conditions that are generated in the room, like the amount of oxygen. So they modify that. But the initial profile is an input. And depending on what's developed in that room with the size that we put in and the ventilation conditions, it can be modified.

MR. BANERJEE: So you do modify it then or you do not?

MR. McGRATTAN: Yes, these models have built into them oxygen limitation, so if we're given a specified heat release rate, oftentimes what that really means is we're given a specified burning rate. And then the model will determine if or if not there's enough oxygen in the room to actually consume all of the fuel that's being liberated.

But the prediction of the burning rate for most practical items is very difficult for the model to do. There's too much uncertainty and practice in the nuclear community and in the non-nuclear community is usually to burn the item of interest, get its heat release rate and specify it in the model. Now oftentimes when you burn the item, you burn it in similar conditions. So if you're interested for example in the heat feedback, you often burn, for example, under some hood that will get hot and then radiate backwards.

When we did work on the World Trade Center and how that building collapsed, we did a lot of experimental work in which we placed the items of interest, typical office furnishings, underneath a steel hood. That steel hood was allowed to get hot, and what we wanted that hood to do was represent a real fire environment in which the burning rate of the fuel is not just dependent on the fire itself but rather the hot gas layer above. So we try as much as possible, when we get these burning rates and heat release rates, to burn the item in an environment that is consistent with what that item would actually see in the real plant.

MR. BANERJEE: But in fact, I mean don't -- your model, the tables you're showing natural ventilation and mechanical ventilation. You're actually charging whether or not your mechanical ventilation and natural ventilation as characteristics fit into the test, so you're considering those?

MR. McGRATTAN: Yes.

MR. BANERJEE: Right? I mean I'm looking here at this table.

MR. DREISBACH: In the experiments that we evaluate, we characterize the ventilation conditions and that is evaluated against the ventilation conditions in the real scenario, yes.

MR. BANERJEE: I suppose what we're saying is Q dot depends on FIVE?

MR. DREISBACH: Sure. Yes.

MR. McGRATTAN: Right. And in fact, Q dot is often limited by FIVE. At some point you cannot get any more heat out of an under-ventilated room.

MR. KHALIK: I guess on a more basic level, Q dot is a dependent variable rather than an independent variable?

MR. McGRATTAN: It depends on how you're doing your analysis.

MR. KHALIK: Well, it depends on -- I'm talking about in real life.

MR. McGRATTAN: Oh, in real life, absolutely.

MR. KHALIK: Q dot is a dependent variable depending on the geometry and boundary conditions.

MR. McGRATTAN: Right.

MR. KHALIK: And you are using it as an independent variable and perhaps you're using it sort of in a parametric iterative fashion until things fit together. Then you know you have the right Q-dot.

MR. McGRATTAN: Right.

MR. KHALIK: Is that the process.

MR. McGRATTAN: Yes. We're quite confident that these models do smoke and heat transport very, very well. However, we're still not at a point where we can make outright blind predictions of burning rates of common materials. We would much rather get experimental data for the source term and put that into the model rather than have the model try to determine that automatically.

MR. PEACOCK: That has been the Holy Grail of fire research for at least 20 years to be able to do that.

MR. BANERJEE: But at least to a first approximation, it should be made a function of fire something, right, in the sense that you may have a burning rate with plenty of oxygen and parametric crises, and then as you decrease oxygen, the burning rate will change.

MR. McGRATTAN: Right. And oftentimes our experiments, to characterize the burning rates of objects, are done inside and outside of rooms. So we often want the heat release rate, for example, of a sofa -- I'm talking more in residential applications -- underneath a hood with plenty of ventilation. We also will put that sofa into a small compartment to represent a living room and get the burning rate there. And then we compare, and we see what the oxygen limitation, how that's having an affect on the burning rate.

MR. KHALIK: My concern about this process is that the user of code of this type can get whatever answer he or she wants.

MR. McGRATTAN: Which is why the heat release rate is often specified by the AHJ. Go back to the McDonald's analogy. Lots of tests have been done on fully flashed-over fires in compartments. They have a fairly good idea of what the upper bound in the heat release rate is going to be. They'd rather use that, that upper bound, for a conservative analysis rather than let the fire modeler try to predict what the heat release rate is going to be.

MR. APOSTOLAKIS: But that's for design purposes of structures that are not subjected to ACRS review.

MR. DREISBACH: Anthony is going to talk more about --

MR. APOSTOLAKIS: In the early PRAs, we did what Professor Banerjee just suggested. We calculated the heat release rate, and we considered cases when it was ventilation controlled in the first approximation or not. So it's not something new. It was done then. It was calculated, you know, in the early code. So it doesn't seem to me that it would be such a big deal to do that. So you guys keep saying it's an input. I mean we calculated it. The biggest uncertainty was there, of course. The mass burning rate is really very much uncertain.

MR. JOGLAR: Well, the -- a quibble into what Kevin said about the McDonald's, that heat rate is prescribed. There are documents that prescribe heat release rates for nuclear applications, and we have to --

MR. APOSTOLAKIS: Where? Where are these documents?

MR. JOGLAR: 6850 has a table of what numbers to use.

MR. NAJAFI: Appendix E. And the basis for it was experiments were conducted to the extent possible to mimic the nuclear power plant and electrical fires. Basically, you're correct. When you build – an initial intensity is driven by the amount of fuel you have, fuel package inside a panel, for example, for electrical, how much ventilation you have, what's the configuration of the fuel, how tightly it's combined, and how it's vented and all of that kind of stuff. So we created something. They created. Sandia National Lab, they created something similar to that and burned it and measured it to get the mass loss rate. And from that mass loss rate, we came up with these distributions that says this is the 90 through some method. So it's documented. That's where a fire modeler, when their initial source is electrical fire in an electrical panel, goes to this document, and it says the heat release rate or mass loss rate is from x to z to y. It's in that range. For a small cabinet, large cabinet, medium, things like that.

MR. APOSTOLAKIS: Yes. Slide 21, though, can you really tell us very quickly how to use that? So what am I supposed to do now? I'm doing a study, and I'm calculating my parameters, right, the non-dimensional parameters? Then what? Then I go here and do what?

MR. DREISBACH: We compare. Okay, so now we have --

MR. APOSTOLAKIS: You compare or I compare?

MR. NAJAFI: User.

MR. DREISBACH: User compares.

MR. APOSTOLAKIS: The user.

MR. DREISBACH: Or the reviewer.

MR. APOSTOLAKIS: I'm the user. Okay. So what do I do?

MR. DREISBACH: So you compare your situation as far -- you calculated 2*d*. We've calculated 2*d* for the experiments that we considered. Your 2*d* should be within the validation range on the right-hand column between 0.4 and 2.4 if you want to make conclusions about your prediction based on the information in this document.

MR. APOSTOLAKIS: Now let me understand this. My 2*d* --

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: -- is 2.1. Okay. I look at all these, and the second column, I think you call it ICFMP, experiment)BE#3?

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: BE#4. Okay. So now what do I do.

MR. BONACA: Go to the validation page.

MR. DREISBACH: On the right-hand side, the range on the right-hand side summarizes all of the experiments.

MR. APOSTOLAKIS: Okay, fine. So what do I do now.

MR. DREISBACH: You're 2.1 is in the validation range.

MR. APOSTOLAKIS: Right.

MR. DREISBACH: So you as a user can now say the predictions that I come up with using the model --

MR. APOSTOLAKIS: Which model?

MR. DREISBACH: -- based on my scenario. Whatever your prediction shows. That's the point. You as a user are providing information to the NRC as the reviewer to prove something or other.

MR. APOSTOLAKIS: Which model, though? I mean you're evaluating five models.

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: Which model am I supposed to use.

MR. JOGLAR: The model is the one in the list of cores that you say that are listed, that has the capability to make a calculation and has our judgment, this team's judgment on how good that calculation is. So if you pick out of that table to calculate a capability with one of those models, then you have to check that your dimensionalized parameters match the ones that we did for these experiments.

MR. APOSTOLAKIS: That's where you lose me.

MR. DREISBACH: This is not providing you the decision to choose one model over another. You have to make that decision using this, using other tools, using the scenario, evaluating your scenario. You make the decision about what model you choose. You then take the information from your model and your scenario, evaluate it against our validation range, and then you're able to use some of the conclusions from the results of this report.

MR. APOSTOLAKIS: But, again, this is a simple thing. I'm trying to understand. I'm interested in the hot gas layer temperature.

MR. DREISBACH: Okay.

MR. APOSTOLAKIS: You're table 31 tells me that CFAST, MAGIC and FDS are green.

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: FIVE and FDT are yellow.

MR. DREISBACH: Within the ranges on the right-hand side, that's the colors that you get.

MR. APOSTOLAKIS: Wait. So I'm saying okay, I'm going to go with one of the three greens, CFAST for example. Then the next step is for me to calculate all these dimensionalized parameters for my problem --

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: -- and come to this slide 21 to decide whether I can actually use CFAST?

MR. DREISBACH: Whether you can make conclusions based on this validation about CFAST and your prediction.

MR. APOSTOLAKIS: What conclusions are

these?

MR. NAJAFI: Well, basically once you decided that all of those codes are green, you chose the CFAST.

MR. APOSTOLAKIS: Yes.

MR. NAJAFI: Then you come to this table. This table tells you that if you're within .4 and 2.4, you are allowed to use the green. But if you're .1, you're not allowed to use the green.

MR. DREISBACH: You have to -- there's a level of confidence that you can use CFAST for that particular scenario.

MR. APOSTOLAKIS: How many of these parameters am I supposed to calculate and come to the table, just one?

MR. JOGLAR: It depends on each case. It depends on the characteristics of each fire scenario. If it's, for example, a small room where ventilation can be critical.

MR. APOSTOLAKIS: A hot gas layer in a small room.

MR. JOGLAR: Oh, then the heat release, maybe the phi, the --

MR. APOSTOLAKIS: B? Okay. Is it possible that 2*d* is 2.1 but phi is 1, so I'm having a problem now?

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: One is within the other result?

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: So what do I do?

MR. JOGLAR: Well, it means, I think, that you can estimate 1, but not the other. I mean it falls outside of the V&V, right?

MR. DREISBACH: Right.

MR. APOSTOLAKIS: No, but this is ridiculous.

MR. BONACA: It depends on the applicability of the scenario.

MR. APOSTOLAKIS: That's where I'm lost now. I want the hot gas layer temperature. That's what I want.

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: Everything else is input.

MR. JOGLAR: But we have to bound the scope of this V&V, because it's not a blanket for every single application.

MR. APOSTOLAKIS: My question is really very simple, unless I'm not posing it -- I choose

CFAST. I want the hot gas layer temperature. You just told me I need to calculate for my room 2*d* and phi, right?

MR. JOGLAR: Yes.

MR. APOSTOLAKIS: 2*d* is 2.1. Phi is 1. What am I supposed to do?

MR. BANERJEE: Nothing. It's outside the range of the validation.

MR. APOSTOLAKIS: Then what?

MR. DREISBACH: You can do any number of things. You can make statements regarding why the phi of 1 is still okay based on your scenario versus our scenarios. You have to make an argument why we or a regulator should accept the analysis if one is outside the range.

MR. BANERJEE: Yes. And you would calculate that the hot gas layer. All this is saying is this V&V doesn't provide validation for that calculation.

MR. APOSTOLAKIS: So I'm left alone in the wilderness to face the NRC then?

MR. DREISBACH: Well, you're not alone.

MR. APOSTOLAKIS: Well, there will be other people who will say in public. Okay. But then -- okay. Now another question. Is it really -- I mean these models, again, CFAST, it did not predict -- let's use that word -- the results of each one of these experiments equally well. Some of them were better than others?

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: So is it reasonable then to take the widest, the lowest bound of the range or the upper bound from all these experiments? I mean what if the best fit was Experiment B#5, which is .7, and yet you're telling me now that for CFAST the range is .4 to 2.4? Aren't you eliminating some of the detail here that may be important?

MR. DREISBACH: The detail is coming later. This is just we're trying to describe the process. What happens is we use the model to calculate all the experiments, and we summarize the data in a set of graphs that we call scatter plots that provide an indication of the measured temperature, we'll say, and the calculated temperature. And we use judgment based on a metric as far as uncertainty is concerned to determine the level of confidence in that range. So there may be points in that range that are not as good as points from another experiment. But --

MR. APOSTOLAKIS: But it's still green?

No, green is based on something else.

MR. DREISBACH: Because they're all within a certain metric of uncertainty. That provides us --

MR. PEACOCK: But there may be other quantities. For example, it gets a yellow because it's good in one area but not so good in another area.

MR. JOGLAR: The colors are our best judgment on this based on all the calculations, and I wouldn't dismiss the situation in which a knowledgeable user could point out the best experiment that fits his case and use that range for a dimensional experiment. That's why all of them are liste there, but that requires big knowledge of how the experiment was wrong. And that information we also provide.

MR. APOSTOLAKIS: Okay. Let's move on then.

MR. KHALIK: This turning point for a lot of this is that the user has to verify that the parameters associated with the scenario in which he or she is interested fall within these ranges.

MR. DREISBACH: Yes.

MR. KHALIK: And if I look at these parameters, Q^{d}*, phi and h over d*, those are the three parameters for which you had a range that the user has to verify fall within these ranges.

MR. DREISBACH: There a few more in the report.

MR. KHALIK: But all of these parameters have Q dot in the definition.

MR. DREISBACH: Yes.

MR. KHALIK: And Q dot is an assumed number, and therefore the user can essentially force the scenario to fall within the validation range by assuming whatever value of Q dot that would satisfy these criteria. So it seems like --

MR. DREISBACH: It's prescribed, though.

MR. KHALIK: -- the user can sort of get whatever answer he or she wants for the scenario.

MR. NAJAFI: That I guess goes back to the question -- this is Bijan Najafi -- that Apostolakis was asking, and I was trying to say that in some other document that NRC and EPRI had developed, there is guidance of how to select a Q dot for a particular scenario. It's not left to the user if they follow that document. Of course, anybody can use outside. But there is guidance out there that is developed by this collaboration between -- it is -- specifically Table E-1 in the NUREG-6850 for example says if you have a vertical cabinet with qualified cable with a single bundle which prescribes how the cabinet geometry ventilation is formed, you have to use a heat release rate that ranges between 70 to 211 kilowatts. And it says the basis of it is Sandia test number umptysquat, that it was done with this similar geometry. So it's not that we leave it out there for a user to pick whatever term they want to dial in. That's part of the generating, and defining the scenario is to characterize the initial source. Intensity is one of the things. There are other things associated with it, but the characterization, there is guidance out there.

MR. HYSLOP: Yes. This JS Hyslop from NRC. I guess I was the NRC sponsor to 6850. The initial conditions, the heat release rates which are used in these cases, you know, as Bijan says, there are single cable bundles, multiple cable bundles, and electrical cabinets. There is a distribution for each one of those. And not only were they based on Sandia data, they were based on data from other tests as well. And so the people developing this distribution, it was a process where they took into consideration the data that was available for these particular types of ignition sources. And that's documented in 6850.

MR. DREISBACH: So in many cases, the heat release rate is prescribed ahead of time.

MR. KHALIK: But does that cover all scenarios in which a user is interested. Let’s say again the sample of spilling 100 gallons of diesel oil in an area that is 5 square meters with a sort of an edge that's 6 inches high?

MR. JOGLAR: Yes, it does. Yes, it does. Because for your specific example of a pool fire, there are clearly specified equations to do that, I mean that are well defined and documented. So for most I would say yes. I mean there may be where we don't know, and it's up to an engineering judgment at the moment and the review process to determine if --

MR. APOSTOLAKIS: So am I to understand then that for most of the scenarios to which these models apply in nuclear plants the parameters, these measurements, parameters will fall within the range or the majority, or you don't know?

MR. HYSLOP: In many cases I don't.

MR. DREISBACH: I would not --it's hard to say the majority.

MR. APOSTOLAKIS: So what do we do then?

MR. BANERJEE: You cannot use that scenario for validation of the parameter. That's the way I understand it, right?

MR. APOSTOLAKIS: No, no, no. It's the other way. I want to use a code to do my PRA in support of NFPA 804 -- 5, 4, whatever -- 5. And I'm preparing my case to come, and I know NRR will review it.

MR. PEACOCK: Then you have to -- it's -- if it falls outside the validation results that are provided here or additional ones in the future, that implies that there is additional work that you would have to do in terms of providing justification that the model was valid to use here. That may be additional test results. That may be additional model comparisons with those test results that says that the model is appropriate for the scenario I'm interested in.

MR. BONACA: For example, the volume of the test and the volume of the room in which the test was done or some other parameters, like ventilation, et cetera, maybe so different from what you are trying to apply it to that he cannot use this comparison for validation. They're telling you you're out of the range of this parameter which is a member -- I mean the dimension of this parameter, but that will give you the guide that says yes, --

MR. DREISBACH: The analysis is obviously limited.

MR. BONACA: -- you can use it for validation, this parameter, but you cannot use it for validating the other parameter. So maybe you can use it only for validating flux but not hot gas.

MR. BANERJEE: I have a much more fundamental problem. How did we pick these non-dimensional groups, and are they actually the ones that are important? I mean I think we should get back to basics on that, because we are asked to accept this as being the -- I haven't seen any justification for these groups.

MR. BONACA: – the way I understood what they were doing. Okay? Now that's a different question.

MR. APOSTOLAKIS: Before we go to Sanjoy's point, Mario, realistically now, somebody's doing a Fire PRA and he falls outside, do you really think they're going to go and run tests?

MR. BONACA: No.

MR. BANERJEE: No, of course not.

MR. BONACA: No.

MR. BANERJEE: Well, that's one of the issues --

MR. APOSTOLAKIS: In fact, most of the

analyses we have seen from the industry are using FIVE.

MR. BONACA: But we heard a comment here that said well, you have all those n/a's that you can now run the test. That's if I understand it. However, you get the most important parameters even with those, so therefore, you know, why worry about that. Probably for a PRA, you would be satisfied with having those parameters, flame height, plume temperature. I'm trying to say that you --

MR. APOSTOLAKIS: Well, the point --

MR. BONACA: -- be able to use that.

MR. APOSTOLAKIS: I understand, but my point also from the practical point of view is that nobody will go out and do those things, because nobody can afford it. It's true that most of the industry PRAs we have seen, or the IPEEEs were FIVE, right? And here is an interesting statement. The libraries of engineering calculations, FTT5-Reg 1 have limited capabilities. These libraries do not have appropriate methods for estimating many of the fire scenario attributes evaluated in this study. Now what do I do? I don't know what to do.

MR. BANERJEE: Well I think, though, there is a point of view where if you have a well-validated tool like your FDS or something, it doesn't strictly have to stay within the parameter range because there is some science there now. It's not just purely empirical. So in a sense, we do this all the time in terms of other things where we do experiments on a scale which is smaller, and we use a computer to try and bridge the gap to full scale where we don't have any experiments. So I think the more strong the science base for a tool is, the better chance you have --

MR. APOSTOLAKIS: Absolutely.

MR. BANERJEE: -- to be able to go outside the precise range of the parameters. I have much more concern, though, with the parameters which actually go into this, like the --

MR. APOSTOLAKIS: I just thought about that.

MR. BONACA: -- heat import and the non-dimensional groups and things like that.

MR. McGRATTAN: I'll address that. These parameters simply fall out of the Navier Stokes equations when you non-dimensionalize them, specifically for fire applications. For example, the 2* is basically a Froude scaling. D* is basically the characteristic diameter of the fire. So all of these people who are doing pool fire experiments, for example, which is nothing more than a circular pan filled with fuel. You're measuring center line, temperatures and velocities. You take the Navier Stokes equation, non-dimensionalize. These are the parameters --

MR. BANERJEE: But I don't see a Grashof number there. I would have expected a Grashof number rather than a Froude number. How is that happening? I mean when I non-dimensionalize the Navier Stokes equation for a flow, I tend to get the Grashof number.

MR. McGRATTAN: Right.

MR. BANERJEE: So there is none here.

MR. McGRATTAN: I don't think we've gone through all of them. I mean we could sit down and go through them but --

MR. BONACA: Sit down and non-dimensionalize the Navier Stokes. Generally, I would get in a buoyancy-driven system, a Grashof number. Said will correct me if I'm wrong, but I don't see that number.

MR. McGRATTAN: Right. And the reason why you're not seeing it here is because most of these models and these non-dimensional quantities are just for mass and energy conservation. Remember CFD is relatively recent and actually, doing these plume calculations is a recent phenomena. So I focus on Grashof numbers and such, but the traditional models, the hand calcs and the zone models don't have a use for that. They have a use for characterizing the geometry of the space and the size of the fire, because at the end of the day when you're using a hand calc or you're using a zone model, that's what you're considering. Now when you're getting into the CFD, that's when you're getting into the dynamics of the flow. And then there are other parameters that come into play. For example, D*, for me, is the most critical parameter, and yet none of other models really have a need for it. D* is the characteristic diameter of the fire. And when I choose a numerical grid, I need to get, you know, x number of cells across that fire to really resolve all the eddies and so forth. So it depends on the application.

MR. BANERJEE: I'm also concerned that if you're doing mass and energy balances for these two-zone models, how does G come into it?

MR. McGRATTAN: G comes into it via --

MR. BANERJEE: That's simple dynamics.

MR. McGRATTAN: -- a plume correlation. A zone model has no flow field. What it has is a correlation that says for a fire of a certain size, you have so much entrainment of air which pumps air from the lower layer into the upper layer. So you have transport of a certain amount of mass and heat from cold zone to hot zone.

MR. BANERJEE: So you're trying to --

MR. McGRATTAN: So it's a correlation.

MR. BANERJEE: -- apply the Navier Stokes in some way?

MR. McGRATTAN: So the Navier Stokes are simply bundled into that correlation which is pulled from the experimental literature --

MR. BANERJEE: It doesn't come out of the equations?

MR. McGRATTAN: No, no, no.

MR. BANERJEE: It comes out of it?

MR. McGRATTAN: No. You pretty much throw the momentum equation away when you're dealing with the hand calcs and the zone models. That momentum equation only shows up when you look at pressure differentials and so forth.

MR. BANERJEE: So there are two scenarios?

MR. McGRATTAN: Yes.

MR. BANERJEE: One which is sort of understandable is whatever non-dimensional groups arise by non-dimensionalizing the conservation equations for the sort of calculation that FDS is doing.

MR. McGRATTAN: Right.

MR. BANERJEE: Well, I would expect that these groups are wrong, because they are not -- they would have other numbers. If I non-dimensionalize them, I won't get these numbers.

MR. McGRATTAN: Right.

MR. BANERJEE: I actually went through your report on the equations. Okay? So if on the other hand you are using a more approximate model, then these non-dimensional groups are arising out of some empirical correlation for whatever the dynamics are. So in that case, it is required that we justify these are necessary and sufficient number of groups that we are using if this is going to be actually given as guidance?

MR. McGRATTAN: Right. If you talk to some of the people who have been around for a long time, like for example Jim Quintiere, what happened was he noticed when he started collapsing his data trying to develop these correlations, he started seeing these groups pop out of his analysis, just purely empirically. At the same time, the fluid mechanicians were getting into it, starting to study the plumes, starting to develop CFD models. They were non-dimensionalizing. And lo and behold, these two groups came together at some point and said, these parameters, the Q*'s, the D*'s, we're seeing the same thing. We're looking at the same non-dimensional parameters coming from the empirical community and coming from the theoretical side. That's what gives me confidence that these are the parameters that we want to focus our attention on, that coincidence, if you will, of the theoretical and the empirical.

MR. BANERJEE: Is the science-base for choosing this documented somewhere in a -- I would say this is fairly critical, because you're asking people to be guided by the choice of these within a certain parameter range?

MR. McGRATTAN: The best documentation for this is what's called this SFPE Handbook, the Society of Fire Protection Engineers Handbook. And what that is nothing more than the history of fire research, and article after article after article, whether you're looking at ceiling jets, plumes, and whatever else, these parameters come up again and again and again. I mean it's hard to say these are the right ones and these are the wrong ones, but these are the parameters that have stood the test of time. They have a theoretical basis. They also have an empirical basis. That's what gives me that level of confidence, because they come from the two worlds that we often deal with in fire.

MR. BANERJEE: Well, I think it's a critical issue to document. I mean in a sense, what you're saying is you have to read a whole handbook to get this feeling of comfort which --

MR. McGRATTAN: Well, you can read -- Quintiere's written a book on fire. Dougal Drysdale. There are a number of experts in the field who have written textbooks documenting these parameters. The Handbook I mentioned simply because it's something that we all use. We all have it on our desks.

MR. APOSTOLAKIS: Can you address this issue maybe using a couple of slides at the presentation to the full committee?

MR. McGRATTAN: Sure.

MR. APOSTOLAKIS: And maybe give a specific reference that some of us who are interested can go and read without reading the whole Handbook.

MR. BANERJEE: We can't be experts at everything, right.

MR. McGRATTAN: Absolutely. I mean --

MR. BANERJEE: We can't, but George can very quickly.

MR. McGRATTAN: We can have a lecture on the history of fire dynamics, fire research.

MR. APOSTOLAKIS: Well, not the history. Please. There is a straightforward question. Provide some of the scientific bases. Now you might want to say, you know, in 1956, this was done, this and that.

MR. McGRATTAN: Right.

MR. APOSTOLAKIS: But at least give a more specific answer to this question.

MR. McGRATTAN: Right. We can do that.

MR. APOSTOLAKIS: I think that will be very useful.

MR. JOGLAR: Yes. Jim Quintiere last year published a book. We went this year with a full chapter on these dynamics.

MR. APOSTOLAKIS: Francisco, I have no doubt that you guys can do it. Okay? But please do it.

MR. McGRATTAN: Okay.

MR. KHALIK: Does D* appear anywhere in FDT?

MR. DREISBACH: D* in the spreadsheet calculation?

MR. KHALIK: That's right.

MR. DREISBACH: Probably not because it's not an important parameter for that type of mode.

MR. KHALIK: Does the ratio page over D* appear anywhere in FTD?

MR. DREISBACH: Not in the spreadsheets, no.

MR. KHALIK: Does the model or the empirical model contained in FTD or FIVE contain the ratio H over D* as an independent parameter anywhere?

MR. DREISBACH: No.

MR. KHALIK: And yet you're asking the user not to use that model outside the range of 3.6 to 16, correct?

MR. McGRATTAN: I guess so.

MR. KHALIK: So where is the connection between the constraint that you're imposing on the range of applicability of a model and the dependence of the outcome of the model on that parameter?

MR. McGRATTAN: These non-dimensional parameters are used to characterize the experiments that were conducted, so H over D* is basically characteristic height of the entire volume versus the characteristic height of the fire. Okay? Or characteristic height scale of the fire. If H over D* is very, very large, what you have is a man smoking a cigarette in a football stadium. And we'd be hard-pressed to say that we could model or that we could justify the use of these models and these experiments for that scenario.

So H over D* is one way that we're using to characterize the experiments. It doesn't have any particular model in mind. It's simply a ratio of two length scales that help to characterize the relative size of the fire to the size of the building. And that does come into play when you're considering whether or not to use this guide.

MR. KHALIK: Well, when somebody develops an empirical model, it doesn't come out of thin air, right? It comes out by fitting some set of experimental data, right?

MR. McGRATTAN: Right.

MR. KHALIK: And therefore, the governing constraint for the use of an empirical model is what is the experimental database that was used to develop that model.

MR. McGRATTAN: Right.

MR. KHALIK: And now how does the ratio of H over D* for which that empirical model was developed, the experiments that were used to develop that model compare with the set of --

MR. McGRATTAN: Well, if you notice in the chart with the colors, the yellow and the green, all those n/a's that you see associated with the FIVE and the FDT, what that means is that those models and the way that they were developed fell outside of the range of parameters of the experiment. So for example, we did an experiment or we looked at experimental data in which we had a large fire in a very small compartment, this so-called pump room example. Well, the ceiling jet algorithms in FIVE and FDT were not appropriate for that experiment, because the ratio of the height to the width fell outside the range for which that was calibrated.

MR. JOGLAR: I see it as two layers of verification. This last table is for kind of practical applications but also in our individual volumes, in chapter three, describe the question that is in the spreadsheet, and it says the range of data that was used to develop that correlation. So kind of both of them have to be checked if you have to use that equation. But that information is in there.

MR. DREISBACH: We can provide some -- as we said, at the full committee, we'll provide some more background of the non-dimensional parameters, but

I'd just like to --

MR. APOSTOLAKIS: Yes. I'd like to come back to the schedule here. We absolutely have to finish at 2:30, because we have another presentation after that, and we have planes to catch. And I think you have too much material here to cover, and I definitely want to hear the summary of results and concluding remarks. So maybe you gentlemen can decide to what extent you want -- and also we agreed that you will walk us through one of the models and one of the tests, how you did it. Is that what we said earlier? I thought we agreed.

MR. NAJAFI: I think we said we will go through the example of how these color-coded things is going to be used. That's what I heard, but if there's other people --

MR. APOSTOLAKIS: Well, not just for the use but also, you know, how did you decide if something is green. Better walk us through the --

MR. DREISBACH: Yes. We can show you that.

MR. APOSTOLAKIS: So if you want to rearrange your presentations to fit the time available, please do, because I see you have presentation on FTD, on CFAST and FDS. I'm not sure we can do all of that.

MR. DREISBACH: Yes. I think one of the --

MR. APOSTOLAKIS: So while you are speaking, maybe Bijan can thing about it, what to cut?

MR. DREISBACH: I think one of the key projects and one of the things that we're somewhat proud of is the way we developed our uncertainty and our method --

MR. APOSTOLAKIS: Of this presentation?

MR. DREISBACH: That's this presentation.

MR. APOSTOLAKIS: So let's go through it then.

MR. DREISBACH: And that's what we'll go through now. And Anthony Hamins from NIST is going to present that information.

MR. APOSTOLAKIS: Well, then think about the rest, what to cut and what to include. Please, identify yourself.

MR. HAMINS: I'm Anthony Hamins of NIST. I'll be presenting Volume II of this V&V study that establishes a quantitative evaluation methodology and emphasizes experimental uncertainty. And then following my presentation, my modeling colleagues will present their results of the evaluation using this methodology.

So this presentation is broken into several parts. First, I'll describe some of the details of the experiments selected for this validation study. Then I'll describe the methodology, including the role of experimental uncertainty in this process. I'll give examples of the analysis highlighting key fire parameters. And finally, our conclusions will be summarized.

This table shows the experiments that were selected. There were 26 tests, 6 experimental configurations. They're listed as shown, chronologically. Four of these tests were specifically designed for nuclear power plant application validation. The first one and then the last three.

MR. APOSTOLAKIS: FM is factoring mutual?

MR. HAMINS: That's correct, factoring mutual. And then S&L stands for national labs. NBS is the old NIST, National Bureau of Standards. ICFMP, four sets of data were provided by ICFMP. This is the International Collaborative Fire Modeling Project. NRC took a lead role in this. So in these six sets of experimental configurations, NRC really was heavily involved in the first one and the last four. And the reason they're involved in finding good data from all validation is because there is a scarcity of well-documented, comprehensive compartment fire test data available in the scientific literature.

MR. APOSTOLAKIS: Well, typically in a nuclear plant, in a compartment, what actually burns?

MR. HAMINS: I' going to defer to my colleagues who are experts in nuclear power --

MR. APOSTOLAKIS: Because these substances that are burning here, ethanol or the propylene are not typical of what one would expect.

MR. HAMINS: That's correct. These are essentially heat sources, fire sources that the intent is to have a well-controlled fire source in order to be able to test the models. Because an essential part of the experimentation and the model comparison is to have a very good knowledge of the heat release rate. Without knowledge of the heat release rate in these steadily burning fires, then the validation, the comparisons would never work, and there would never be a good comparison between models and measurements.

We are not at the point where we can predict fire spread from this corner in this room through the building and to the building next door. We're just not there. So in this study we have used steadily burning pool fires typically or spray fires in a well-controlled, regulated manner in order to provide a constant heat release rate for which the models can be compared. So we're looking at the thermal environment of this compartment and how it changes as the fire continues to burn. And we're observing.

MR. APOSTOLAKIS: They are surrogates for whatever would be the materials burning --

MR. HAMINS: That's right.

MR. NAJAFI: Let me add something to it, because there is a little bit more to it than that. For example, the first one, the propylene is the initial trigger of the fire. The actual 500 kilowatt is not coming from that fuel material. they took an electrical panel, a cabinet, a metal cabinet. They loaded it up with cable bundles, some to the tune of about 100,000 megajoules or something. So they took massive cable and put it in there. The propylene or that some kind of fuel trigger was used, because they could not electrically infuse a cable fire. So basically that's what is used to ignite the cable.

MR. BANERJEE: Is that true of all of these cases? I mean this is very confusing --

MR. NAJAFI: No.

MR. BANERJEE: Because I mean if you call it a fuel, we assume propylene is the fuel. You are not saying the fuel is actually the cable.

MR. JOGLAR: That's true for the first row there.

MR. BANERJEE: Which ones are true, which ones?

MR. JOGLAR: The first row, it was cables burning after they were ignited. The other ones are the actual fuel that you see. So it's actually cables.

MR. HAMINS: There were actually cables in B#3, and I believe in B#5. However, their contribution to the heat release rate happened at very late times in the experiment. We did not use that portion of the data for the validation. The principal fuels as listed I believe are correct, and they vary in the type of hydro carbonates being burned. For example, ethanol is a lightly-sitting fuel whereas acetylene is a heavily-sitting fuel. This has impact on radiative heat transfer.

We tried to cover a parameter range that encompassed a broad range of fuel types. And you can see on the heat release rate, there was about a factor 40 difference between the different experiments. The volumes varied by about a factor of 20, and the heights of the compartments varied by a factor of 8.

Two of the experiments, the heat release rate was determined through mass loss measurements. For the experiments, heat release rate was determined by what's called oxygen consumption calorimetry, and I can go into the details of that if you are interested.

Here we explain how heat release rate is measured experimentally.

MR. BANERJEE: So how is the heat release rate for the first set of experiments determined?

MR. HAMINS: Yes. For the FM-SNL test, oxygen consumption calorimetry was used. The fuel flow was also measured. And from the equation that's shown in this slide, there is a there is a consistency then between the burning rate and the measured heat release rate. That is through what's called the combustion efficiency. Inside the compartment, we slowly used the oxygen. As we become visciated, the efficiency of combustion changes.

MR. APOSTOLAKIS: We don't have this slide.

MR. HAMINS: I'm sorry. This was slide 13, and I felt this was more important to show immediately, so I'm showing it now. So experimental heat release rate drives fire affects, and it's uncertainty dominates model sensitivity. So we focus our attention in the experiments on the heat release rate and on the uncertainty associated with it. There are two ways that it's measured as I've shown here. And you can see from the FM data, for example, that there is some variation. The measurement has some uncertainty. Okay. Let's look at the next.

MR. APOSTOLAKIS: Before you go from that slide, you said that M dot is measured and KI_A is estimated. What is the typical range of KI_A?

MR. HAMINS: Yes. It's fuel-dependent because acetylene, for example, produces copious amounts of soot. In other words, you're not producing CO2 and water vapor. And thermodynamically, you're not producing complete combustion, so it's a reduced amount. It's a factor then of how complete the combustion is. It varies. For heptane, for example, it's on the order of 85 percent approximately. So for other fuels like acetylene, depending on the scale, depending on the ventilation conditions, it can be 50 percent. So we've looked at each of these experiments and tried to estimate what the value of the combustion efficiency is and what its uncertainty is. That was the job that we did in Volume II.

MR. APOSTOLAKIS: So this is the input uncertainty, right?

MR. HAMINS: This is the uncertainty in the experimental measurements. The key input parameter -- we find the most sensitive parameter in all of the models is the heat release rate.

MR. APOSTOLAKIS: Right.

MR. HAMINS: Yes.

MR. APOSTOLAKIS: That's what we just discussed.

MR. HAMINS: Yes.

MR. APOSTOLAKIS: So that's an input uncertainty?

MR. HAMINS: That's correct. For the models, it's an input uncertainty, yes.

MR. APOSTOLAKIS: Now you're talking about experimental uncertainty?

MR. HAMINS: Yes. And we lump both what we call model sensitivity to input parameters which are experimentally based and experimental measurements. We lump them all together as experimental uncertainty. And I'll try to describe that concept in a moment. So many of the test reports, unfortunately, do not provide uncertainties for the individual measurements. Some do, but where that was not true, estimates were based on previous experiments at NIST using similar instrumentation. Measurement uncertainty itself depends on the exact type of the instrumentation, the experimental procedure and the details of the measurement scenario.

I'd like to talk first about BE#3 which was performed at NIST in 2003. This was a project funded jointly by NRC and NIST. It was part of the ICFMP series of projects. You can see the heptane spray fire burning in the background. This was a large compartment, 22 meters long, 7 meters wide, 4 meters tall. It was the most comprehensive set of measurements conducted at NIST/NBS. There were 10 to 7 data points taken, 350 measurements -- instruments were used per test. We measured the heat release rate using oxygen consumption calorimetry. We measured the fuel flow to assure that it was consistent with that result. We did another consistency check by looking at the energy balance. Where did the energy go, out the door, through the walls, energy enthalpy going to heat up the compartment gases? So through these consistency checks, we felt that we were getting a pretty good handle on the uncertainty.

MR. BANERJEE: What's the spray as opposed to a pool fire?

MR. HAMINS: Yes. A spray fire is simply fuel emanating from a nozzle that is impinging onto a flat plate. It's a very nice way to control the rate of delivery of a fuel, and we've been using it extensively at NIST. We were able to provide 400 to 2300 kilowatts through these spray fires. We were looking at the thermal environment in these compartments. And they were instrumented with cables. We were looking at heat flux to targets. We were looking at heat flux to the wall. We were looking at the gas space temperatures at seven horizontal locations to try to understand the vertical temperature gradient inside this very large compartment.

Experiments were conducted with open and closed door and with mechanical ventilation. There was a mechanical supply duct and exhaust duct on opposite sides of the compartment. The detailed flow through the ducts was measured using PITOT tubes and what's called bidirectional probes. Our intent was to document all the boundary conditions and initial conditions. We measured thermophysical properties of surface materials and their optical properties. We need to know the imocivity of the surface materials.

Those were measured at NIST. We tried to nail down the boundary conditions for validation effort.

I'd like to go on now and discuss briefly some of the other experiments. I conducted the --

MR. BONACA: These experiments, I mean you have a -- you do not address fire propagation, I guess?

MR. HAMINS: That's right. We are not testing the models for fire propagation. We're looking at steady burning.

MR. APOSTOLAKIS: None of the experiments did that?

MR. HAMINS: That's correct.

MR. BONACA: Does it mean switchgear room you have all these cabinets --

MR. HAMINS: Of course.

MR. BONACA: -- you will have propagation?

MR. HAMINS: And there was a fire in an electrical cabinet, as Bijan mentioned, in this particular set of experiments. However, I believe, if I'm not mistaken, the cabinets were empty, and there was no contribution to the heat release rate during the period of time which we were interested in looking at model validation.

So this was a one meter propylene gas

burner in the middle of the room. Again, this is a big room, 18 meters by 12. As I was saying -- just let me mention one more thing, I was the PI on B E number 3. We spoke to the PIs on all of the experiments in order to really try to understand and make sure we understood the instrumentation that was used, to make sure if there were any questions about the documentation and the reporting in order to really be able to do the best job possible on estimating on measurement uncertainties.

The NBS tests were conducted in 1985. Rick Peacock was involved with those. A corridor connected two rooms. A rather small natural gas fire was in the back of one of the rooms, and the thermal environment was measured.

MR. BANERJEE: How did you measure -- you did this oxygen calorimetry you said on --

MR. HAMINS: Yes.

MR. BANERJEE: -- the other ones? What sort of methodologies were used to estimate the heat release rates?

MR. HAMINS: Yes. Mass loss was measured by placing a load cell, which is essentially a strain gauge that's water cooled to avoid thermal affects. Underneath, a pan of fuel. And as the fuel evaporates, the mass loss gauge instrument gives a voltage reading which is calibrated. So we're able to follow as a function of time the mass loss. Then through assumption of the combustion efficiency and understanding the heat of combustion, idealized heat of combustion, we're able to estimate the heat release rate for that fire.

MR. BANERJEE: How did you make an estimate of the combustion efficiency?

MR. HAMINS: Yes. The combustion efficiency is not well understood for visciated compartment fires. It's not understood for all fuels. The scientific literature was consulted. New experiments at NIST are looking at combustion efficiency, and we have some good information on that from those experiments. What we're trying to do there is look at the thermodynamics, so we measured the exhaust products, measure all the species, and from that one can calculate thermodynamically what the efficiency of combustion is. That's how we got a handle on --

MR. BANERJEE: You sort of postulated certain reaction paths based on the species you saw and looked at --

MR. HAMINS: No. We didn't postulate.

Just thermodynamically one can calculate based on heats of formation without any kinetics. Just looking thermodynamically, one can estimate what the combustion efficiency was by measuring gas products in the exhaust stream.

MR. BANERJEE: And you'd have to measure soot as well, right?

MR. HAMINS: Yes. Soot was measured. Sure.

MR. KHALIK: Slide number five, I think you skipped over that?

MR. HAMINS: That's possible.

MR. KHALIK: Slide number five, there.

MR. HAMINS: Well, not the one that I have. It says FM Sandia National Lab.

MR. DREISBACH: It should be six.

MR. HAMINS: This one?

MR. KHALIK: Should be six. Maybe six. Okay. Now this is inconsistent with what was said before in that these are 500 kilowatt propylene gas burners. And what was said before was that the propylene was just the initial trigger of the fire.

MR. HAMINS: I believe that's not correct. I'll stand by my statement that this was a propylene gas fire.

PARTICIPANT: Anthony Hamins is correct. When we made the statement, we were confusing two sets of Sandia experiments. And what is in this is correct. It's actually a propylene fire.

MR. KHALIK: Okay.

MR. NAJAFI: This test was done as a test to measure the affect of a fire outside of an electrical panel. The example that you set panel to panel fire, so there was an empty panel, fire source, another empty panel, and they measured the temperature on the surface inside the adjacent panel and in the center of the adjacent panel. So that was the idea to --

MR. APOSTOLAKIS: But that's a different experiment.

MR. NAJAFI: Correct. I want to correct what I said. That was a different set of experiments.

MR. KHALIK: So for the record, the statement that you made earlier was incorrect.

MR. NAJAFI: That is correct. For the record, that was a different experiment, not this one. It was done also at Sandia and Factory Mutual. That's what confused me. But that's a different experiment.

MR. HAMINS: Okay. The next set of experiments were contributed by VTT Finland. These were experiments in a very large turbine hall. This was part of the ICFMP project. The experiments were conducted in 1998, 1999. Twenty meter tall sloped ceiling, 27 meter long. This was the largest volume that was tested. There were four types of measurements conducted here looking at hot gas layer temperature and depth, average flame height and plume temperature. The heat release rate in this experiment was determined form mass loss.

MR. BANERJEE: And, again, analysis of the gases?

MR. HAMINS: Yes. The next experiment is BE#4. This is from Germany as is BE#5. Here, a one meter square pan of jet fuel in a compartment with concrete walls was tested. It's a very large fire in a small compartment. We're trying to look at a wide parameter range of G* and D*. The heat release rate in this experiment also was determined from mass loss rate. There were some instrument malfunctions and fluctuations later in the test. That part of the data set was not used. We focused on high quality data.

MR. BANERJEE: PITOT tubes as well for the velocity field?

MR. HAMINS: The velocity field here I don't believe was -- oh, inside the exhaust duct, there was no -- in this experiment, no. Because mass loss was used to determine the heat release rate. In the next experiment in Germany, BE#5, the exhaust had to measure the mass flux through the exhaust in order to determine the heat release rate. But the velocity field inside the compartment was not measured.

MR. BANERJEE: But temperatures were?

MR. HAMINS: Temperatures were measured, yes.

MR. BANERJEE: Vertically and horizontally?

MR. HAMINS: Vertically and at three locations vertically I believe. Several locations vertically.

MR. KHALIK: So in the experiments where you have a fuel spray, I can see how you can control Q dot to make it constant with time so you get a top hat distribution of Q dot.

MR. HAMINS: Yes. Right.

MR. KHALIK: But what is the time history of Q dot when you have an experiment of this type. There must be some strong time dependence of Q dot.

MR. HAMINS: Yes, there is.

MR. KHALIK: And what value would you then use to characterize this?

MR. HAMINS: Here are two examples. One, BE#2 on the left, and FM data on the right. So the mass loss data in BE#2 is shown, was determined from the load cell. Then that measurement was converted. And here you see the time-bearing heat release rate. So what I showed in the table was approximately the maximum or peak value for that case.

For the FM data in the table, I listed the steady burning value which, on average, was about 450 kilowatts as you can see from the plot shown here.

I was trying to characterize, give you a feeling for the types of heat release rates that were investigated and used for the comparison to the models.

MR. BANERJEE: With the gas burner also you can, I suppose, keep a relatively constant --

MR. HAMINS: Absolutely. Yes.

MR. BANERJEE: Yes. But it's the, I guess, the load cells, as you said, it's just burning off of must have some variation.

MR. HAMINS: Okay. These were the parameters that were predicted by the model.

MR. APOSTOLAKIS: Let's stop for a moment here. In the report, you make a very explicit statement about intrinsic uncertainty. You say model intrinsic uncertainty is uncertainty associated with the physical and mathematical assumptions and methods that are an intrinsic part of the model formulation and its implementation. And this uncertainty is not part of the model input uncertainty. The methodology for examining this type of uncertainty is described in Reference 43, which happens to be a thesis from the University of Maryland. And there is no other information provided.

Now when I hear, without reading the report, that you are validating models, I sort of expected that you would address what you call intrinsic uncertainty. But you're saying, no, go somewhere else. And I don't even know how -- what Maryland does there and whether it's an accepted way of doing it.

MR. HAMINS: There are --

MR. APOSTOLAKIS: Isn't that a little strange for a project of this magnitude to dismiss this model intrinsic uncertainty in four lines?

MR. HAMINS: May I address your question?

MR. APOSTOLAKIS: Of course.

MR. HAMINS: And perhaps Kevin would like to chime in. We were going to move towards the sensitivity analysis and how experimental uncertainty was used in this process, in this methodology development. There are certain uncertainties that we are not able to quantify. For example, the approximations to the Navier Stokes equations, how k-epsilon modeling versus LES modeling may be better or worse in some cases. There are a whole slew of approximations used in the model development. We can't get a handle on those mathematical assumptions. What we do, and I'll try to show that in the next few slides, is we have a more stringent uncertainty bound. And by having this more stringent uncertainty bound, we're asking for the model calculations to fall within these uncertainty bounds that are narrow. And it makes the comparison more challenging. So we are fixating on a portion of the uncertainty, not the entire uncertainty which makes the validation even more challenging and difficult. So we agree that there are certain uncertainties that we cannot characterize, and we have to find a resolution. We're moving on with the validation using the methodology that I'll describe. And we would welcome your comments.

MR. JOGLAR: But I wold like to add in this Volume II, we are defining what uncertainties we are capturing, and those are reflected in the uncertainty bounds that Anthony is describing. When we plot our results, the comparison between experimental data and models, we see if they fall in or out of these uncertainty bounds which, again, are capturing the uncertainty that we could quantify. And in my personal opinion, that in and of itself suggests where model uncertainty issues should be. Because if you're falling outside of these uncertainty bounds that we can calculate, then it's perhaps because the model is introducing some uncertainty. So our results may suggest model uncertainty issues that we should explore later. That goes to your original comment, but it's not that we are not considering them. It's just we're quantifying the uncertainty that we can. And when we see our results against those, that suggests where there may be other sources of uncertainty such as model uncertainty.

MR. APOSTOLAKIS: But the intrinsic uncertainty is there, right? It's there. I mean in the red line you show there, the red curve, it is there.

MR. HAMINS: Yes.

MR. APOSTOLAKIS: So it does affect the results. And you're saying here: however, a sense of the size of the intrinsic uncertainty of the models can be ascertained from the results of this study, and the question is how?

MR. HAMINS: From the difference between the models and the measurement results.

MR. APOSTOLAKIS: So then the uncertainties -- I mean the uncertainty in the inputs -- I just don't see --

MR. HAMINS: Can I go on and try to explain --

MR. DREISBACH: -- move along, and we'll explain more completely --

MR. HAMINS: I think the next --

MR. DREISBACH: -- your issues.

MR. HAMINS: The next two slides will help answer some of your questions.

MR. APOSTOLAKIS: But one last question. "The methodology for examining these type of uncertainties is described in reference 43." How did you decide that that methodology was appropriate?

MR. DREISBACH: I don't think the statement say anything about appropriateness of that methodology.

MR. APOSTOLAKIS: If you say that it is examining as described, it implies that if I want to do something, I can got to Reference 43.

MR. JOGLAR: I have tested that methodology.

MR. APOSTOLAKIS: You have what?

MR. JOGLAR: Tested it. I have tried it using information generated from this project. It's not documented in the project that I did, but my personal experience with it suggests that this data is useful for that method; and that method, it has practical applications for like Fire PRA.

PARTICIPANT: But we don't know what the method is, though.

MR. JOGLAR: Well, the method basically say I calculate the number using a model. What is the probability that that number is real, it represents the reality.

MR. APOSTOLAKIS: That has been the question from day one.

MR. JOGLAR: Well, it's another methodology to address that. I mean our exercise that we did at EPRI is documented in a conference paper, so I mean our experience with it is that it's useful, but it's, as you say, another method to address that question.

MR. APOSTOLAKIS: Since you used it, then why didn't you put it in the report?

MR. NAJAFI: That was not clear. At the initial time that we started this project, it was not within the scope of this project. As it was intended, this was to validate and verify these models. As a user end, this may be a subject for the User's guide project that you will see basically. And there is a project that Jason will describe at the conclusion that we are contemplating to move into a document called the user's guide of this document. How do you use this color coded. That may be a topic to be included there, how do you use it even within a probabilistic framework, which is what it is. How do you get the results of this document and use it, if you wish, within a probabilistic framework and uses that methodology and applies it to this.

MR. APOSTOLAKIS: Let's go on.

MR. HAMINS: This slide shows a typical experimental result and a model calculation for the temperature. These are actual data that were used in the validation study. So the fire at time zero was turned on. The temperature in the upper gas layer temperature, the average temperature was determined through experiments. It peaked and we denote that peak as E_p. That's the experimental maximum or peak value of the temperature at about 600 secs. Then we turned the fire off, and the temperature decayed. The model predictions are also shown.

The question we're trying to answer is how to compare these two curves. So what is a good basis for comparison of these two curves. There have been many studies that compare experiments with models, but they have essentially qualitative in nature. We've tried to develop a quantitative evaluation. This work is similar to a 1997 CFD study, used a similar methodology. It was published in *J. Fluids Engineering*.

Where experimental is used as a metric, as the basis for comparison between these two curves -- and I want to highlight the fact that we compared the peak values. We did not compare the entire curves. We compared the peak values. And let me mention one other thing. ASTM does not give specifics on how the two models and experiments should be compared. They give general guidelines. The methodology developed here is unique for fire science.

MR. APOSTOLAKIS: Were the peak values usually at about the same time?

MR. HAMINS: Yes. The data was monotonic, and the peak values may have varied a percent or two, but not much more than that. They were very similar.

So here I'd like to describe the methodology. So we define a relative difference between the models and measurements, and it's a non-dimensional number, epsilon we call it, normalized by the peak experimental value. And this might be temperature or heat flux or whatever parameter of the 13 parameters we're looking at.

We also determine -- well, let me go to the plot again. So I've re-plotted the data. The same plot now is shown with uncertainty bars for both model and experiment. And in this approach that we're using, we're asking the question is there overlap of the uncertainty bars. That's essentially the basis for comparison between models and measurements that we're using. And the derivation of this combined measurement in model uncertainty is in the Volume II. I don't want to go through all the details.

MR. KHALIK: But just for clarification, the line that you call model prediction uses the nominal values of the parameters for the experiment? Is that correct?

MR. HAMINS: The uncertainty in the models?

MR. KHALIK: No. The red line, the solid line in the model prediction uses the nominal values of all parameters.

MR. HAMINS: Those were the calculated results from the models --

MR. KHALIK: Using?

MR. DREISBACH: Using the specified --

MR. HAMINS: -- characterization of --

MR. DREISBACH: -- nominal values of the independent variables.

MR. APOSTOLAKIS: And the red uncertainty on the left is due to what?

MR. HAMINS: Yes. It's sensitivity to uncertainty and input parameters such as heat release rate.

MR. APOSTOLAKIS: So you said for this particular experiment, we're not really sure what the heat release rate was, but here is a range, and if I put that in the code, I get this?

MR. HAMINS: Yes. That's right. Then we --

MR. APOSTOLAKIS: It's really a combination of both input uncertainty and model uncertainty, intrinsic uncertainty.

MR. HAMINS: Yes.

MR. APOSTOLAKIS: Because it's there.

MR. HAMINS: Well, the model uncertainty

would come out -- any variation of the model uncertainty from reality comes out in the model calculation.

MR. APOSTOLAKIS: Yes.

MR. HAMINS: And it would be included in the sensitivity to the input also. Yes.

MR. BANERJEE: Yes. I suppose you -- model uncertainty, let's say you were using something like the epsilon model, so then you have these seven or eight parameters you fool around with, and they actually have some range of variability. and if you put that in, you'd get an uncertainty there based on varying those. But you haven't done that type of an uncertainty analysis. You're just fixing it at whatever the model parameters are fixed at. Or if you're doing say LES, it would be the Smagorinsky constant. You're just taking some Smagorinsky constant. You're not looking at the sensitivity of the results to the Smagorinsky constant?

MR. McGRATTAN: Not in this analysis, no.

MR. BANERJEE: Right.

MR. McGRATTAN: I mean we do that off line, but not here.

MR. KHALIK: So how are the error bars then determined around this red line?

MR. HAMINS: The error bars were determined for the model through sensitivity to uncertainty in experimental input parameters.

MR. KHALIK: And that was done with box statistics of some sort?

MR. HAMINS: I'm going to go through that in a moment. And I'll show you that. And the experimental uncertainty was determined for each particular instrument looking at repeatability and propagation of error for that particular instrument.

The plot on the right then is a summary for CFAST for the temperature results for all 26 experiments for both temperature and hot gas layer depth. And these sorts of plots -- you'll see it in the modeling section -- the idea here was to get to the combined uncertainty provides a value for which we can compare to the relative difference, this epsilon. And you'll see these lines on these types of plots. And the and the question is how well do the experimental data, do the relative differences fall within these variants of epsilon which we call the combined measurement and model uncertainty. So the question is shown on the left side of the screen, is epsilon less than U_c, the variants expanded relative uncertainty of the measurement and models.

MR. APOSTOLAKIS: U_C then is a standard deviation?

MR. HAMINS: Yes. It's the expanded standard deviation. It's a standard deviation two times the standard deviation, so 95 percent confidence internal. Okay?

MR. APOSTOLAKIS: U_M squared is the variance of the model uncertainty?

MR. HAMINS: Yes.

MR. APOSTOLAKIS: And the other one is an experimental uncertainty?

MR. HAMINS: Yes.

MR. APOSTOLAKIS: So if I take the square root of the sum of the squares, I get the variance?

MR. HAMINS: Yes.

MR. APOSTOLAKIS: I mean the standard deviation.

MR. HAMINS: Yes.

MR. APOSTOLAKIS: What did you say about two times?

MR. HAMINS: Well, I'm saying it's the capital U in all three cases are expanded. They are not standard deviation. They are used with a factor of such that the confidence on a Gaussian-type distribution of results when one does a uncertainty analysis, one then would have more confidence to look at two standard deviations than one standard deviation.

MR. APOSTOLAKIS: So the U_M squared then is four time the variance of the model predictions?

MR. HAMINS: Capital U refers to the expanded uncertainty.

MR. APOSTOLAKIS: So it's four times?

MR. HAMINS: Yes. Okay? Here's an example then of model sensitivity to uncertain input for the hot gas layer, average temperature in the hot gas layer. And here we use an empirical correlation developed by Quintiere. And it was substantiated over 40 years of fire experiments that the hot gas layer goes like the heat release rate to the two-thirds power. And then looking at the change in the hot gas layer then is related in the second equation.

So if there is an uncertainty in heat release rate measurements of roughly 15 to 25 percent for all of the experiments that were considered here, then the prediction, the model predictions must vary by about two-thirds of that or about 10 to 16 percent. A sensitivity analysis confirmed this relation by looking at the models and propagating the sensitivity to the heat release rate through the models.

And this was done for all the parameters. That's shown in this table. There is a power dependence with Q, that is the heat release rate, to all the 13 quantities on the left side of this table. There are other parameters that become important also, such as in heat flux the radiative fraction. Other things that come into play are the height of the doorway for example and the hot gas layer depth and the soot, for example, the soot yield and the smoke concentration.

So the power dependence was typically two-thirds, but it varied from parameter to parameter.

Now I'd like to talk about the experimental uncertainty and again use the example of the hot gas layer temperature, the average temperature in the hot gas layer. In the experiments I've described, in almost all of them, gas phase temperatures were typically measured bare-bead thermocouples or aspirated thermocouples.

MR. BANERJEE: I just want to clarify. I can see how you did that sort of model uncertainty for the two layer-type models. How did you do that for the FDS-type model?

MR. HAMINS: The FDS model provided detailed information locally, and we treated it the same way by using a standard reduction technique to determine the average upper layer temperature and lower layer temperature and depth.

MR. BANERJEE: And then you just phased it into this?

MR. HAMINS: Yes.

MR. BANERJEE: All right.

MR. HAMINS: So here again is the hot gas layer discussion for the experiments. Experimental data is shown on the left, and then using this reduction technique, we take that data and determine the average upper layer temperature and lower layer temperature as well as the layer depth, the hot gas layer temperature and depth, use this two layer reduction method. And then propagation of error analysis considered the form of those equations as well as the uncertainty of the temperature measurements, the temperature locations and the spacial resolution of the temperature measurements which was very important. There is a certain distance between the thermocouples in the experiments. In some experiments, they were very crude, a couple of meters between each other. So we didn't have information between the thermocouples where the hot layer dept was. So the spacial resolution was an important consideration in all of the uncertainty estimates for the various parameters.

MR. KHALIK: Excuse me. Did you translate the uncertainties in the primary variables into uncertainties in the non-dimensional quantities?

MR. HAMINS: Yes. Everything was propagated through, if I'm not mistaken. No? Oh, no. They were done in real dimensional quantities and then we non-dimensional quantities.

MR. KHALIK: So do we know what the uncertainties in the non-dimensional quantities associated with the various experiments are?

MR. HAMINS: You mean the range? For example the Q* and the D*?

MR. KHALIK: Right.

MR. HAMINS: We can do that. We haven't done it. But one could do that certainly. Because we've listed what the uncertainty is in the heat release rate, one could determine what the uncertainty in the Q*'s are.

MR. KHALIK: So all the uncertainty analysis was done using the raw variables?

MR. HAMINS: Yes.

MR. KHALIK: Okay.

MR. HAMINS: So then here is a summary of the uncertainty results where we've combined them, model and experimental uncertainty for each of the six tests, for the hot gas layer depth and temperature. And one can see that there was a variation in the experimental uncertainty, for example, for hot gas layer depth. That varied by a factor of 2, almost-- actually a factor of 6. Very little difference in the uncertainty on the model. The combined values are shown in yellow on the left side. On the right side, we look at the hot gas layer temperature uncertainties. There was again variation among the experiments and among the models and uncertainties as large -- combined uncertainties as large as 30 percent on the temperature for one of the tests and as low as 12 percent, 10, 11 percent.

MR. APOSTOLAKIS: This is for what model?

MR. HAMINS: No. This was using the correlations that represent the fire physics, so one would expect,, for example, in the hot gas layer that an uncertainty in heat release rate would lead to an uncertainty in the hot gas layer temperature based on the Quintiere correction, which I showed earlier. And all the models have that physics built into them.

MR. APOSTOLAKIS: Oh, okay. So but it refers to that correlation which is used by several models?

MR. HAMINS: Yes.

MR. APOSTOLAKIS: Not all.

MR. HAMINS: Here is the table then that lists all the weighted combined uncertainties. We've taken and tried to simplify the analysis by providing one combined uncertainty that was weighted based on the average uncertainty from all the various tests. And it's provided in this table. And this is the number then that's used for each of the parameters in order to do the comparison with the experimental results and the model results.

So I'd like to conclude and summarize that a quantifiable evaluation methodology was developed in which experimental uncertainty is used as a criteria for validation. Both experimental and model uncertainties were considered. The determination of uncertainty was considered as important as the measurement itself.

We conclude that experimentalists need to do a better job of documenting and reducing measurement uncertainty if fire modeling is to be advanced. And the magnitude of the uncertainty in each of the results can be used to prioritize efforts to improve measurement accuracy. And we plan to do that in the future.

MR. APOSTOLAKIS: Let me ask a question. Let's go to the previous slide. Again, from the point of view of the user, if I use that correlation to calculate the hot gas layer temperature, and it gives me a number, then this table tells me that the uncertainty about that number is 14 percent up and down -- no, 14 percent total, right?

MR. HAMINS: The expanded uncertainty for the measurements and models was 14 percent in this case.

MR. APOSTOLAKIS: That means that it can be 14 percent higher and 14 percent lower?

MR. HAMINS: Yes. In terms of -- now this is the relative variance.

MR. DREISBACH: I think we need a background. The calculation you make as a user, this is not going to give you the uncertainty of that calculation necessarily. This uncertainty is just used as a metric based upon the experiment.

MR. APOSTOLAKIS: Yes. But I'm trying to figure out how to use it for the future. So is it associated with this particular correlation but it can be 14 percent up and down?

MR. DREISBACH: That was the reason why we stepped back from trying to quantify the inherent model uncertainty, because we have a variety of models and different technique as far as level the of sophistication in those models. We needed an approach that used a different metric by which to characterize the uncertainty.

MR. APOSTOLAKIS: Explain to me then what this 14 percent means.

MR. HAMINS: This is the variance of epsilon, what we've show in that table. that table include U_c. And U_c is the variance of epsilon. So epsilon is the relative difference between models and experiments. That's normalized by the experimental result. And the U_c which was in that table then is the combined measurement and model uncertainty which is the variance of epsilon.

MR. APOSTOLAKIS: Okay. So an epsilon of 2.7 tells me that the model over predicts, right? And that there is uncertainty about that prediction which has this variance?

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: So why can't I use that in my application? I mean I'm trying to use this now and go and do a PRA for my plant. And I'm using this correlation to calculate the hot gas layer temperature.

MR. HAMINS: Can I try to answer that? The question is how uncertain was that epsilon determination. There is uncertainty in the models. There is uncertainty in the measurements.

MR. APOSTOLAKIS: Right.

MR. APOSTOLAKIS: If we're within those uncertainty bounds, then we have, we say, validated the model. The model has predicted within experimental uncertainty the experiments, within experimental uncertainty, within uncertainty of the measurements and the models, it has -- the combined uncertainty. So that's the basis for our comparison is to look at the variance of epsilon and epsilon.

MR. APOSTOLAKIS: I understand what you did. Now I'm taking again the user's point of view. I'm using that correlation to calculate the temperature in the hot gas layer in my plant. I have compared the dimensionalized parameters, and I'm within your ranges.

MR. JOGLAR: We are saying that that is the best you can do and you phil confident of that. You don't have to do anymore work. That's what the green represents.

MR. APOSTOLAKIS: Let me ask again the

question. I have my plant, and my parameters fall within the ranges, and I calculate from the correlation a temperature say of 400 degrees. What does this 14 percent mean to me?

MR. HAMINS: If refers to a particular set of experiments. This value of U_c that was determined is an average weighted value for the experiments which I've represented. For the user, that's a -- it's like comparing apples and oranges. It's a different situation.

MR. APOSTOLAKIS: So I do not have then an estimate of the uncertainty in my calculation.

MR. JOGLAR: Well, if you do all the checks with the dimensionalized parameters and you fall within that, what this suggests is if you calculate your hot gas layer, that will be the uncertainty that is associated with it, but that's the best we can quantify given the uncertainty in the experiments.

MR. APOSTOLAKIS: I don't get the same answer from Mr. Hamins.

MR. HAMINS: No. It's true. We're getting guidance on the variation between the models and measurements from the epsilon. From that value of epsilon, we're seeing what is the goodness or agreement between models and measurements. The uncertainty then gives us a guide on what we can do with the model calculations as far as expectation of goodness to fit. For example, we see the pressure has a very large weighted uncertainty. We can't do better than 40 percent for pressure in the experiments that we've conducted. On the other hand, gas concentration is 10 percent. So if one is using a model, than one can say one will do better on gas concentration. It will be on the order of magnitude of 10 percent uncertainty in the calculation as compared to an experiment expectation, as compared to pressure where one would expect to be further off.

MR. BANERJEE: But this is U_c you're talking, is that it?

MR. HAMINS: Yes.

MR. BANERJEE: Yes. But what is epsilon?

MR. HAMINS: Epsilon is the relative difference.

MR. BANERJEE: Right. I think I --

MR. HAMINS: And it's shown in this plot. It's plotted about zero, so the results are plotted about -- so here, we plotted about zero the results. So epsilon can be positive or negative, and it falls above or below the zero line. The question is if I can -- I'm sorry --

MR. BANERJEE: I think it's clear what Ụ is here in your table. If you calculate the hot gas layer temperature, you could say, okay, I am plus or minus what percentage --- it's here -- let's say 14 percent. But that's the best we could do given our experiments.

MR. HAMINS: Sure. But --

MR. BANERJEE: But we don't epsilon yet, right?

MR. APOSTOLAKIS: No. I don't know epsilon. And the other thing I don't know -- I mean why are you saying -- I mean you are implying that the estimate of the code is the best estimate, and you have uncertainty about it. And if the code has intrinsic uncertainty, systematically over estimates or under estimates, that's not true.

MR. HAMINS: Oh, no, that's --

MR. BANERJEE: In a way -- the way I look at it is that we have collected in these uncertainty bounds inputs to the model like the heat release rate, that uncertainty. We have collected uncertainties from the instruments, and we have developed this range in which we then plot. So if we are outside of there, there are other contributors to uncertainty. Like, for example, so maybe a physical issue with the model, I mean of the physics. And that is not in those lines. And that's what I was suggesting before, that as soon as you start getting far out of these lines, then there are --

MR. APOSTOLAKIS: Again. Let's -- you are really focused on what you have done, and I'm taking the point of view of the user now. I'm going to do a PRA, a Fire PRA, go to my room, okay, the cable spreading room or whatever. I calculate the dimensionalized parameters you gave me, and I'm within the ranges. So I'm happy. I run the code or the correlation through the Excel sheet, and I get 400 degrees. Now, I have to make a statement about how confident I am that the 400 degrees is in fact 400, and I'm trying to figure out how I can use your results here to make a statement regarding my confidence in the 400 degree estimate.

One answer I got is that it's 14 percent up or down with 90-some percent confidence. And my answer to that is that can't be true because it assumes that the 400 degrees, the best estimate is a central value, and uncertainty is up and down, and it could be systematically over or under estimating the result.

So, again, what am to do. I don't know epsilon. Do I know epsilon? Do you give me an epsilon here? In other words, if you tell me that epsilon is always 2, then I know I'm always over predicting. But then I still have a problem with the up and down.

MR. JOGLAR: I guess that's the issue if you go back to the epsilon U_c. This is giving you U_c, right?

MR. APOSTOLAKIS: Right.

MR. JOGLAR: Let me see -- is your question.

MR. BANERJEE: We don't understand what epsilon is.

MR. APOSTOLAKIS: Epsilon is, I guess, the --

MR. BANERJEE: Yes. We know what it is there, but how is that being delivered?

MR. APOSTOLAKIS: Right. And how does it apply to my calculation when I do it in the future?

MR. JOGLAR: Okay. How it applies, it's based on the dimensionalized parameters

MR. APOSTOLAKIS: I admit that. I satisfied those requirements.

MR. JOGLAR: So I guess what I'm trying to suggest is much simpler -- if I understand correctly your question that if you meet the dimensionalized parameters, and the answer that you get is -- and we have classified, given this analysis, the model capability as, for example, green -- that's the end of the process. You did the best you can, and the validation supports that calculation.

MR. APOSTOLAKIS: Take out the 400 degree temperature. How confident am I in that? Can I get an answer to that?

MR. JOGLAR: If we classified it as green, the team thinks that you should be very confident.

MR. BANERJEE: I guess he's saying that epsilon is less U_C if it is green? Is that why you are really saying?

MR. JOGLAR: Yes.

MR. HAMINS: Yes.

MR. DREISBACH: Yes.

MR. BANERJEE: All right.

MR. APOSTOLAKIS: You're saying that epsilon --

MR. DREISBACH: The characterization of the model's predictive capability is simple there.

MR. APOSTOLAKIS: Well, but that's a major observation. My goodness.

MR. DREISBACH: We have to deduce this. It's not said anything yet.

MR. APOSTOLAKIS: Say that again? I have this 14 percent.

MR. DREISBACH: If you make the prediction from CFAST --

MR. APOSTOLAKIS: And it's green. I use a green code.

MR. DREISBACH: Regardless of what model you use, you find that your model is green and you're within the range that we say you're within, but predictive capability is green, you don't need to worry about any of the other numbers.

MR. BANERJEE: But does green mean that epsilon is less than your U_c.

MR. DREISBACH: Yes.

MR. BARANOWSKY: Lets not say it's absolute, because their clearly is engineering judgment in this. But the answer is, y es, it's very close.

MR. APOSTOLAKIS: So the 14 percent is something that I will not use?

MR. DREISBACH: Correct.

MR. APOSTOLAKIS: All I use is the green?

MR. DREISBACH: Correct.

MR. APOSTOLAKIS: So I can come to the NRR people here and say I am 95 percent confident that the 400 degrees is in fact 400 degrees?

MR. JOGLAR: Yes. The colors represent the best judgment of this team based on these analyses.

MR. APOSTOLAKIS: No, no.

MR. DREISBACH: No. That's not what he's saying.

MR. APOSTOLAKIS: No. He said, no. The 14 percent was used to declare it green?

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: But then it's not for me to use?

MR. BANERJEE: well, I would have thought the logic -- maybe I'm understanding this wrong -- the logic is that if it is green, then the systematic error that you might have between what you call epsilon there lies within U_C? If it is yellow, maybe it lies outside. So U_C then bounds the error possibly, right?

MR. APOSTOLAKIS: But that is still an error.

MR. DREISBACH: Yes.

(Chorus of Yeses)

MR. HYSLOP: This is not really any different than what we do in thermohydraulics when we're looking at ECCS. What they're saying is they have a measure of whether the computer code prediction has a goodness of fit that's acceptable within this range called U_c, not with the uncertainties on it. And we have the same thing if we're computer peak cloud temperature for instance during a loss of coolant accident. We've computed peak cloud temperature, and based on running through similar activities, we only come up with a single estimate of what the temperature is. And we don't look at what the variation or variants on that temperature is and factor that into some risk calculation. And they're not proposing to do the same thing here.

What they're saying is this represents a good calculation within the uncertainty that we can resolve to the best of our ability for the experimental and modeling that they've looked at.

MR. KHALIK: It still has uncertainty.

MR. BANERJEE: But what is implied, what they're not saying is that you also have an estimate of this U_c which is the expanded variability.

MR. HYSLOP: Yes.

MR. BANERJEE: So really you have that.

MR. HYSLOP: And you could expand your analysis to account to the uncertainty in that estimate and propagate it through the risk model if you wanted to do, which is in essence what they did in NUREG-1150 for the containment parameters. They didn't only come up with their best estimate of the parameters. The came up with the ranges and then they picked distributions, which you also could apply here, so that if you predict a peak temperature of 400 degrees using this, say, green V&V'd model, you might also have a 50,, 60 or even 100 degree potential error in that with a certain likelihood.

MR. APOSTOLAKIS: Which does not flow from this.

MR. HYSLOP: Which you could get form this but is not what they're purpose is.

MR. APOSTOLAKIS: I'm not sure you could.

MR. KHALIK: What is being plotted here on the right.

MR. APOSTOLAKIS: All this is telling me is that if I meet all these conditions, I am using a code that has performed well in the past.

MR. HYSLOP: Yes.

MR. APOSTOLAKIS: It is not telling me how uncertain I am about the predication of code?

MR. HYSLOP: Well, it does in part, because you understand through the U_C how uncertain you are in the predication. And you would have to go into the details to see what that is.

MR. APOSTOLAKIS: The 14 percent I was told is not a measure of how uncertain I am in the prediction of the code.

MR. KHALIK: What is being plotted here on the right is the value of epsilon, is that correct?

MR. HYSLOP: That's correct.

MR. KHALIK: For each individual experiment.

MR. HYSLOP: That's correct.

MR. KHALIK: And the line that says 13 percent is what you estimated U_C to be, right?

MR. HYSLOP: Yes.

MR. KHALIK: So if I look at this graph, I say well, roughly half the experiments were less than U_C and the other half had uncertainty for a relative difference greater than U_C. So I'm not sure where you get the 95 percent confidence level associated with that number that you have in the table at the end.

MR. PEACOCK: This particular one, I think, is somewhat a special case. If at the end one of the things we particularly say for both zone models is that for the hot gas layer temperature, the calculation is acceptably green, to use a strange phrase, for where the fire is. But the ones that are outside, particularly the ones that are most outside that 13 percent are ones remote from the fire. That doesn't get a green. That gets a yellow, ,because we've decided that's far enough outside the U_C bounds that we're not comfortable saying it's always going to be good.

MR. APOSTOLAKIS: So in this example where epsilon is .27, it's outside the range?

re; Correct.

MR. APOSTOLAKIS: Therefore, what? It's a yellow?

MR. PEACOCK: Therefore, you need to --

MR. APOSTOLAKIS: It's a yellow?

MR. PEACOCK: It's a yellow in this case.

MR. APOSTOLAKIS: It's a yellow. But for NRC purposes, though, if I look at the curves, it's pretty good, because it's conservative.

MR. JOGLAR: That's why we have a yellow plus, for practical applications.

MR. PEACOCK: Conservative if you're interested in maximum temperature. If for example I am interested in detector activation, the fact that the model predicts it rising faster implies that it's going to predict the detector goes off faster than it does. So it depends on the application whether it's conservative or not.

MR. APOSTOLAKIS: Well, why don't we then, because of the time, ask you to give us a more definitive at a different committee meeting? The question is --

MR. DREISBACH: Definitive answer to what question?

MR. APOSTOLAKIS: I'm doing an analysis. I get 400 degrees. What can I say about my uncertainty about that from your results.

MR. DREISBACH: Okay.

MR. APOSTOLAKIS: Okay? That's the purpose of subcommittee meetings, to identify.

MR. PEACOCK: That's a very good question.

MR. APOSTOLAKIS: Thank you very much, Pat. And on that happy note, I don't know now. Can we afford an hour for lunch? Half an hour? So we'll be back when, at 1:00?

(Whereupon, the matter went off the record at 12:21 p.m. for a lunch break, and back on the record at 1:10:04.)

MR. APOSTOLAKIS: Okay. We're back in session. Who's next?

MR. DREISBACH: We're going to go right to the results, the final presentation.

MR. APOSTOLAKIS: Very good.

MR. DREISBACH: And then if we have some time left over, we'll go in the model by model --

MR. APOSTOLAKIS: Yes. We also have to discuss at the end your presentation to the full committee.

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: So let's jump to the results.

MR. DREISBACH: Bijan's going to start out the summary, go through that.

MR. APOSTOLAKIS: So which presentation is this?

MR. NAJAFI: This is where it says summary results.

MR. DREISBACH: The last presentation.

MR. APOSTOLAKIS: Okay.

MR. BANERJEE: We are not going to hear about FDS? I was looking forward to it?

MR. DREISBACH: If we have time. We're trying to get to the crux of our report, and we hope a lot of the questions so far. And then if we have time, we'll go through the individual model results.

MR. APOSTOLAKIS: So that's the very last four or four slides?

MR. DREISBACH: Yes.

MR. APOSTOLAKIS: Okay.

MR. DREISBACH: Bijan's going to start it.

MR. NAJAFI: Yes. Actually, we're going to go through -- I mean this presentation I've added in the middle of this -- we talked this morning about an example -- I mean at least what is in our mind, or my mind, or collective mind, how the results could be used. I'm sure we talked about that through this sometime during this morning, but I mean I think that's one of the most important things. We need to get a couple of messages in mind in here.

One, in my mind, a better understanding of what is the product that we have in front of us. I want to understand whether we like it, whether we think it is done, finished, to the end, or where it should be, or whatever. I think we need to make it clear what it is that we have. And I think there is some confusion. And hopefully, hopefully, I think that's the first step that we have to jump, that we make sure everybody has the same understanding of what we have.

The second is that I will attempt, through either an example or a process, show you, at least in my mind, how I fit, how I think that product, as it is today, can meet the need. And maybe not 100 percent, but how it cane serve it's purpose today. Where we go with it a year from now, that's a parallel path. In my mind, we have to decide how we can use the product to support all of our stakeholders with the product we have at hand.

Also, I'll start with something maybe very fundamental to show basically what is the process -- I mean please be patient -- Some of these may be obvious and self-explanatory, but in my mind, serves purpose -- This is a process that a user will go through. First a user defines a fire modeling objective.

And what objective means, what that step means is a user will take a question -- a question is, for example, I have found a hole in my fire door. That's a question. What do I do? So I have -- To define the fire modeling objective, I have to take that question -- or the question may be a PRA -- what is the fire risk associate with the control room in plant x.

I have to take that question and translate into a set of fire scenarios or conditions that I can use these fire models to evaluate the conditions. So I take that objective and translate it into I need the upper left corner of the room at the surface of the cable tray x. So that is the purpose of step one. That's the first think you have to do, take the question and decipher it down to a specific measurable thing. That's what we do.

MR. APOSTOLAKIS: Bijan, do you envision any questions that are not related to risk?

MR. NAJAFI: Yes.

MR. APOSTOLAKIS: Like?

MR. NAJAFI: Insurance. NEIL does that all the time. In fact, NEIL is developing their own risk-informed package of how to risk-inform an insurance practice.

MR. APOSTOLAKIS: Yes. But that's risk-informing it.

MR. NAJAFI: Risk-informed, what we call, may be sometimes performance-based is used to determine adequacy of a fire protection feature or system using fire modeling alone. So if --

MR. APOSTOLAKIS: In the regulatory arena, would there be any case where --

MR. NAJAFI: Without risk?

MR. APOSTOLAKIS: -- you do not need risk and use these models?

MR. NAJAFI: It depends.

MR. APOSTOLAKIS: In Appendix R for example, I don't think there is any room for models like this, is there?

MR. NAJAFI: Oh, it could be. It could be. I'll give you an example. If somebody came and said in a lot of those thermo lag days issues that were found that you had to protect -- had no risk, and it was implied that the risk was adequate if you protected the, safe shutdown train of interest in a room. So if you protected it, risk was fine. So if somebody found out that that material, instead of withstanding a three-hour fire can only withstand a two-hour fire now, you could use the fire modeling if you can demonstrate theoretically that a fire exposure that you get from the hazard in the room is equivalent to a three-hour fire in a tested configuration, because that rating comes from a fire test.

MR. HYSLOP: So the bottom line, George, is that you can have exemptions to the Regulations that would use fire modeling results to determine whether or not a barrier is challenged or whether the hazards are significant in the room.

MR. APOSTOLAKIS: But is it fair to think or to assume that the majority of the cases will involve some sort of risk analysis?

MR. HYSLOP: I'm in research, not in NOR, but I'll take a guess at it anyhow. I think with the voluntary rule, NFPA 805 requiring a risk analysis with the agency moving risk, the tools developed, the Fire PRA standard, there's a lot of effort going into Fire PRA. So I would expect a lot of Fire PRA applications using these tools.

MR. APOSTOLAKIS: In fact, I recall vaguely that we were told in one of our meetings that the majority of the plants are going towards 805. Is that the correct --

MR. HYSLOP: You mean more than half?

MR. APOSTOLAKIS: Are planning to, not just --

MR. HYSLOP: The last I heard, there were 41 plants or units that had submitted a Letter of Intent, and there are some plants that are planning to do a Fire PRA that haven't submitted. They're just going to do a Fire PRA.

MR. APOSTOLAKIS: So then a major use of this will be some sort of risk analysis?

MR. HYSLOP: That is correct.

MR. APOSTOLAKIS: I mean NFPA 805 explicitly says somewhere there that any requests for changes will be submitted to the Regulatory Guide 1174, right? So let's --

MR. APOSTOLAKIS: So let's have in mind -- I know that it means nothing to you gentlemen from NIST, but for us, it's an extremely important Regulatory Guide, as you guys know. So a user will have those things in mind. Now I agree that there may be other cases or there are other cases where, you know -- okay, let's go on.

MR. NAJAFI: Yes. I do put a risk assessment as one application of fire modeling, yes. Maybe the most important one but --

MR. APOSTOLAKIS: That's why this is a Reliability on PRA Subcommittee.

MR. BONACA: But those models were not originally designed or developed because of PRA, right?

MR. APOSTOLAKIS: No.

MR. NAJAFI: Some.

MR. APOSTOLAKIS: We realized when we developed the methodology for fire risk assessment that we needed this step. And the first thing you do is, of course, what's out there and over the period of years, EPRI developed FIVE. Then we found out that NIST had CFAST. The French, EDF, developed MAGIC. So, you know, the goal was to utilize the expertise of the fire safety people to do a decent job for our purposes. Okay, step two.

MR. NAJAFI: Step two. The step two, basically once you have defined what you're objectives are, you have to go into the room and collect or define the right fire scenarios and characterize them. And what I mean specifically, I'll go through an example if we can, the next two slides that I gave you, the examples of those scenarios. What is important to recognize -- there was a lot of talk about the uncertainties and various forms of uncertainties that we in this project, we've tried to sort of dissect the problem of input uncertainty to the extent that we call it the input, for example, the characteristic of the fire source. Understood that when you put the fire source into a fire model, the intensity may change because of oxygen limitations and all that, but the initial characteristics of the fire at its start, at time zero, it needs to be defined. That is the uncertainty that we deal with somewhere else. As part of the characterization of the fire scenario, we deal with that. And right or wrong, there are methods to do that.

So that part of it -- and that relies a lot on your objective. If your objective is risk assessment, you may pick a different set of scenarios. If your objective is to determine or establish the adequacy of a fire door or your suppression system, you may pick different fire scenarios. So depending on what you're looking for, you may take one, you may take ten, and you have to take those that engulf or encompass or challenge the objective.

So the next step is where you start picking your -- look at what model do I use. That comes out of many things. One of them is what is it that your scenario wants? Does it want a temperature in a room? Does it want a plume temperature? Is it a radiation scenario? Is it a smoke? Is it important, the smoke generation? So those attributes that you defined in your fire scenario goes into selecting what model you should pick.

So that's the first step that you come into our document. At that point, you start looking at our document and say, I'm going to look at that picture that is at the end to see what is the capabilities of these models, not how these capabilities -- a combination of what model can do what and what model can do what thing better or not better. So that, as a first iteration, that's the first time you jump into our document. It says let me pick -- for example, if I am using the plume.

MR. APOSTOLAKIS: Do we have this?

MR. DREISBACH: No. This is something that's just been created.

MR. NAJAFI: I just created it as you were talking about it over there. I picked out --

MR. APOSTOLAKIS: But you will give it to --

MR. DREISBACH: We can, yes.

MR. NAJAFI: Yes. This one basically gives you an example, and I'll go through it. This is basically a switchgear room of a typical nuclear -- of a power plant. This is a problem we designed for one of the training courses. This is a room that is a Division A room. This is the Division B tray, and it's wrapped in a protective device, a thermal barrier. The target that is in this tray, if it's damaged, the only way to get out of the scenario or system requires a manual action. A manual action needs to be taken here. So the issue here is, do I have enough protection? So do I have a fire that can threaten this or not?

MR. APOSTOLAKIS: Bijan, maybe you can use a cursor so you can speak to the microphone? The cursor to point on the screen.

MR. NAJAFI: So I mean tell me if I'm dragging this too long -- short on time.

MR. APOSTOLAKIS: No, you're fine.

MR. NAJAFI: Basically, what we're trying to say is do I have any fires that can threaten this one, and at the same time can generate enough smoke that I cannot take a manual action here. So there's a, let's say, two problem. I'll pick the first one. The issue is a three-hour rated barrier, ERFBS means Electrical Raceway Fire Barrier System, has been determined to provide only half an hour of protection. Is it enough? That's the question. That's our issue. General objective: Is half an hour fire rating adequate for this hazard in this room. Fire modeling objective: Estimate surface temperature of the cable inside the cable tray.

MR. NAJAFI: So now I go into the next one. This is how we see it. My fire modeling objective is to estimate a temperature. The ERFBS is in the fire plume, so that's the scenario. I went and looked at the scenario, and scenarios in the room says it's a fire that is sitting right in the plume of a switchgear. I know from somewhere else, the NUREG 6850, I have some documented place that it says for a switchgear, this is a heat release rate I should use. Outside for a minute, let's assume that this is not a high energy arcing fault. I mean I don't want to make the problem too big.

MR. BANERJEE: what is HEAF?

MR. NAJAFI: High energy arcing fault. Treat that as a thermal fire, not a boom. It's not a bang. It's just a thermal fire for the moment. So there it tells me use a 500 kilowatt fire because switchgears looks like this, and look like this, and we've done tests and that and that, so it's a 500 kilowatt fire with that distribution, plus or minus x percent. So first I come from Table 3-1, which is the color-coded stuff. In that color-coded stuff, it's telling me that I can use basically -- I don't have it here -- but if you look at that color-coded in your handout, there is one that it shows, a green, and one that is shows a yellow plus. So I could use one of those. Okay?

So user first selects the first Five-Rev-1. This is where I'm getting a little bit to what this product is and what it's not.

MR. BANERJEE: Has the non-dimensional

groups entered here?

MR. NAJAFI: Good question. I missed that point. I'll add it here. Good question. Basically, that's when you put it together in a hurry. But first user selects basically, let's say, Five-Rev-1, because that gives me a yellow plus, and I know that I can accept some level of conservatism. I go into the dimensionalized group, enter my scenarios, which is the volume of that room, the size of 500 kilowatt, and all of that.

First, I determine do I pass the funnel. If I don't, what that tells me -- that -- because remember I said we have three pieces that we have to make fit, experiment, model, reality. If I don' pass the first funnel, our experiment and the reality don't fit. For example, I want a small room, and all I have tested are gigantic rooms, and that makes a difference. That's what would make the claim on the dimensionalized group, that if you don't fit, sorry, my experiment is too far away, too from your scenario. So on experimental uncertainty go through that and you pass, then you use Rev-1. The user selects Rev-1 and obtains, after the dimensionalized groups, obtains a plume temperature of 600 degrees, let's say, okay, which is a 100 degrees below the target damage criteria with a distribution, again, in one of the Appendices of 6850.

MR. APOSTOLAKIS: No. Here you don't need a distribution, because you are claiming the 600 degrees is a conservative estimate.

MR. NAJAFI: Okay. That's exactly. Then I say there's no damage, and that's all I can say. I say no damage because I was yellow plus and I passed the first funnel. No damage. Now, if Five-Rev-1 estimates plume temperature of 850, let's say. I did Five-Rev-1 estimates vdid a plume temperature of 850. I can assume a damage. Damages have occurred. Or use MAGIC. Okay? Because that give me a green. What is says is that I think our five for that is too wide, but we think it's on the conservative side. We could make that conclusion based on our numerics in the Appendices. Our MAGIC came within that experimental uncertainty. So we said that it's green, as good as it gets.

MR. APOSTOLAKIS: I like the way it sounds. Our MAGIC came within --

MR. NAJAFI: As good as it gets.

MR. BANERJEE: Keep on sharpening your pencil until you get the answer you want.

MR. APOSTOLAKIS: Then there were will be another code miracle.

MR. NAJAFI: The thing is that there are models that do better than --

MR. APOSTOLAKIS: I understand your point. So the message here, the way I see it, is that I, as a user, will never use epsilon and your U_C and all that. All that was used to declare the code yellow plus or green. As far as I'm concerned, this is not information that I can use. I am using it when I use the color?

MR. NAJAFI: You're correct in the sense that I go back to what I said this morning. That's why I call this a pseudo quantitative method. We built this from bottom up in a quantitative sense. But we put a qualitative layer for the end user at the top. Our layer at the top is not quantitative.

MR. APOSTOLAKIS: Right. Now, regarding Five-Rev-1, I understand. It's yellow plus --

MR. NAJAFI: Take model x model y. I could have put them --

MR. APOSTOLAKIS: But when it comes to MAGIC, though, and I get a plume temperature of 650 degrees, because it's a more realistic code, right -- you declared it green as opposed to yellow plus -- don't I really worry about the uncertainty now?

PARTICIPANT: It's best estimate plus uncertainty.

MR. APOSTOLAKIS: Plus uncertainty. And that's the part where you are not helping right now with everything.

MR. NAJAFI: No. I know. That's why my point was -- that's what I said during lunch to these guys. I think we need to present what this product is. We're not claiming this product is a lot of things, and we don't need to claim that it's everything.

MR. BANERJEE: MAGIC gives you let's say something like a best estimate of FDS, correct --

MR. NAJAFI: MAGIC --

MR. BANERJEE: -- terms that we understand.

MR. NAJAFI: MAGIC gives us the results that it's within our experimental uncertainty.

MR. BANERJEE: When it's green.

MR. NAJAFI: Yes. When it's green.

MR. BANERJEE: It gives you something which we understand is a best estimate, right?

MR. NAJAFI: That is correct.

MR. BANERJEE: Now normally, when we come to sort of decisions about this, it's best estimate plus uncertainty.

MR. NAJAFI: You're absolute--

MR. BANERJEE: Where is that uncertainty.

MR. NAJAFI: It's not here. That's why I tried to say -- I mean I'm not trying to oversell this. That uncertainty, when we present the green, we're presenting the green as what it is, which is that best estimate. We do not --

MR. BANERJEE: But how do you come up with 650 and your limit is 700? What are we to do with this?

MR. NAJAFI: When we get to that point, I would say we are -- with those limited set, we are probably at the same situation we were with the IPEEE. We will try to be prudent if that is close enough. I know there's judgment involved. There's no question about it. In the past when we used it, when we got 690, 680, we basically said, assume damage. If we got 600 -- I know there's subjectiveness involved -- we do not present a systematic model or methodology of how to deal with that in this product. We don't.

MR. BANERJEE: But let's say instead of temperature we have something to do with pressure, we saw that your uncertainties on pressure are very large. I mean you had different uncertainties on different parameters. So as long as it was temperature, maybe the uncertainty was 15 percent, but when it was pressure, it was 40 percent. So how do I use my engineering judgment at this point? I have no idea if I'm a user that U_C is 40 percent in one case, 15 percent in the other case. I'm just taking the green and hoping for the best, right?

MR. NAJAFI: You're correct. But at the same time, that's why those documents, those experimental uncertainties are included in the body of the report so that a user knows that even if you're using a green, because there is still a large experimental uncertainty versus a green, which is within a very small experimental uncertainty --

MR. BANERJEE: But green, it could still be green --

MR. NAJAFI: With a large experimental uncertainty. Yes, I understand. I think --

MR. BANERJEE: But epsilon could be less than your U_C, so in rough terms, it could still be green?

MR. NAJAFI: Yes. And --

MR. BANERJEE: But I don't know what the number I get means now. Imagine that I had a pressure calculation and I need it to be below 1-1/2 atmospheres, and this came in at 1.2 atmospheres.

MR. NAJAFI: Let me try to add something. It may help somewhat. I know that there is, even within the green, you pick on the pressure. There is -- I mean I don't know if --

MR. BANERJEE: Pick on anything. I mean it doesn't matter. As long as we know --

MR. NAJAFI: No. What I want to add here is that there is some hierarchy or priority or level of use, let's put it this way, to these attributes. The good news is that most of the attributes that are commonly used in most nuclear power plant fire scenarios, the answers are -- basically these colors are more useful. Those are plume temperature in many rooms, because a lot of rooms that are -- and if you look at plume temperature -- in fact, you can look at the hand calculations, and if you can live with the conservatism, they do a, I mean, at least an adequate job.

MR. BANERJEE: May I suggest something. If you go back to the slide where you were giving us the steps, there should be -- just as you were saying here that you should add examination of the range of parameters --

MR. NAJAFI: Yes. That step is missing.

MR. BANERJEE: Yes. You might want to also say that people should look at U_C for their various parameters for the point they are, so they at least get some guidance as to how accurate the model is for whatever you're predicting.

MR. APOSTOLAKIS: Apparently, though, we have differing opinions as to your organization of that, not among ourselves but also I sensed the previous, Mr. Hamins, that he was reluctant to say use the 14 percent as an indication of uncertainty.

MR. NAJAFI: Yes. That's why --

MR. APOSTOLAKIS: I really believe you guys should address this question at the full committee meeting, because it's an important question. You don't have to respond, you know, here.

MR. NAJAFI: But I'm trying to understand what the question is.

MR. APOSTOLAKIS: The question is, I use a green. I get 600 degrees. I have damage at 650. Now I worry about the uncertainties. I mean it's green, it's good. Yes. But it could be 660, with what probability, right? I'm close to the failure limit now, so I have a best estimate calculation, and I want to know why kind of uncertainty goes with that. But the question is, is your effort answering that? The answer may be no. I mean it doesn't have to.

PARTICIPANT: If you know, we should --

MR. NAJAFI: I mean I would -- back to my -- rest of the team disagree with me if I am -- take the leap of faith or go on the limb and say the answer is no.

MR. APOSTOLAKIS: But you're not?

MR. DREISBACH: At least directly --

MR. NAJAFI: No. We're not.

MR. DREISBACH: At least directly, we do not address it.

MR. APOSTOLAKIS: Okay. That's my impression, too.

MR. NAJAFI: I mean if any of you --

MR. APOSTOLAKIS: The next question I have for you is, is this the end of this collaborative project, or are you -- you mentioned the user's guide.

MR. NAJAFI: The user's guide is the plan or the scope. And the goal and objective of it is yet to be defined. It's under planning by the Office of Research and EPRI.

MR. APOSTOLAKIS: But there will be a user's guide?

MR. NAJAFI: If you ask me, as an individual on the record, I think that is one of the key roles of a user's guide, because EPRI did do a fire modeling guide. And that fire modeling guide -- in fact, the chart that you saw, the steps of the fire modeling is right out of the EPRI's fire modeling guide. What that new guide should do is basically integrate the results of this V&V ad what EPRI did prior to that V&V to create a new user's guide that takes into account how do I interpret the results of fire modeling not that I know the results of this V&V exactly answering your question. How do I do that? And that may be the charter, may be, of that user's guide.

MR. APOSTOLAKIS: How about this big NUREG that we reviewed recently. JS, it was 6850, was it?

MR. HYSLOP: Yes, that was it.

MR. APOSTOLAKIS: I mean wouldn't you refer to that at all? I mean --

MR. NAJAFI: There is a question also that we have thought about it, that is what is the interface of these two documents, because the NUREG, EPRI 1011989 basically has a section of a -- has a section on fire modeling, and those fire modeling, it says basically go pick your scenarios, pick your model for fire risk assessment and calculate.

MR. APOSTOLAKIS: Okay. So you will give us a more definitive answer next time. You already said no, and I agree with you, but you will have two or three weeks to think about it. And it's perfectly all right to say that this is something that you will do in the future.

MR. NAJAFI: So it was my goal coming to this afternoon's meeting to make clear what this product is, and this product is qualitative as it's surface. Does it give a distribution of green or yellow or other? No. As far as I know, it does not.

MR. APOSTOLAKIS: It does not.

MR. NAJAFI: Should it? We can talk about that.

MR. APOSTOLAKIS: The other thing I would like you guys to address -- are you done with this?

MR. DREISBACH: With this. Yes, we're done with that. If you understand the color-coding, because I was going to talk through that a little bit more.

MR. APOSTOLAKIS: Yes, we do. We do?

MR. BANERJEE: In rough terms. As any fine structure in this large scale understanding we have.

MR. NAJAFI: And if I have gotten the two messages across that this is what this product is and what it's not, number one. And there is still -- it is very important that within the users of today, there is a place for this product to be used, in my opinion, as a user. Because I've been involved in any of the fire risk assessment and the fire modeling, that I think there is a place, as I mentioned here, for the product as it is today.

MR. BANERJEE: I was just going to ask you -- I mean I understand, I think, what the product is, but I am not sure that if I was a user I would know completely how to us it, and if I get say the temperatures out of it, and it's close to the limits, I don't know what close to the limits means here. That's really the issue, because if the limit was as George was saying, 650, and I come in at 600, now it could be that that 50 degrees is a very large difference compared to the uncertainty in my results, or it could be very small, and I don't have a feel for that. That's why I'm very uncertain about the end use. I think this is sort of a step in the right direction, but by itself, this product does not sort of give me, at least me, the information that I would like. If I come in with a number here, whether it's temperature, pressure, smoke concentration, doesn't matter, I'd like to know how wrong I could be so I know how far I am away from the limits.

MR. DREISBACH: Well let's, just as an example, this is our chart.

MR. BANERJEE: Yes. So I take green.

MR. DREISBACH: It's green, yellow, so here is an example of what green versus yellow is. So on the left, we have MAGIC.

MR. APOSTOLAKIS: Use the cursor. We don't see your finger.

MR. DREISBACH: On the left, MAGIC hot gas layer temperature rise. On the right, CFAST rated the fluctual targets. So what we're plotting is measured temperature rise and predicted temperature rise. So it's obviously at the peaks. That's what Anthony was describing before, and we've got these dotted lines that describe what the uncertainty bands are.

MR. BANERJEE: But these are different on different predicted quantities, right?

MR. DREISBACH: Yes. That's correct.

MR. BANERJEE: So if I understood how, in rough terms, you arrived at green is when your epsilon was less than U_C.

MR. DREISBACH: Yes. So that's what you see on the left side.

MR. BANERJEE: Okay. Let's take that as a working definition. So in laymen's words, let's say the difference between your experiment and your model predictions were within the uncertainty in bolts.

MR. DREISBACH: Yes.

MR. BANERJEE: I mean you add it up in some ways.

MR. DREISBACH: Yes.

MR. BANERJEE: Okay. So that gave you green. If it was outside, it went to yellow. If it was -- okay. Now, I still don't know an answer to my question, whether 600 is okay when my limit is 650 or it's not okay, because if the uncertainty band there was more than 50 degrees or something or more than 20 degrees, then I would say if it was, let's say, less than 20 degrees, 600 is fine. If it's more than 50 degrees, 600 is not fine. So how do I use the prediction from this? Green gives me confidence about the veracity of the method that it is within the experimental uncertainty, experiment plus model uncertainty. However, now I've got a prediction. I don't know what the uncertainty is on that prediction, and that I need in order to be able to use it. So I see this only as a step on the way. It's not yet.

MR. NAJAFI: Well, I mean while it's true that it can be said that this is a step towards that goal, I want to also point out that in our supporting document, in our calculations in the numerics, we point out some of the sources of those uncertainties, even though if we do not quantify it and in the end we don't give you a number, because we don't have that method to calculate an uncertainty at this point. We give you some of the sources of those uncertainties, and if you know the sources of the uncertainties there are currently applications such as SDP that they calculate a number and make a decision in the ROP process -- I'm not speaking for the AHJ -- I mean based on experience -- and those determinations are made based on one estimate with some understanding of uncertainty without necessarily quantifying the uncertainty of whether when I use that model or calculated the temperature under SDP plus or minus 100 or 200 degrees. That is currently being used. I mean it's being used.

I do understand your point. That's why even thought it's not exactly defined as a practitioner, when we got within maybe some discomfort level of our own, we said, okay, this is a failed, assume it a failed. Because there are so many uncertainties beyond that that you don't want even -- where do you find the cutoff? Yes. It is -- I mean --

MR. BANERJEE: So giving an upper bound and a lower bound, perhaps that would be useful.

MR. NAJAFI: Well, all I can say for that, we're not there now. Because I can tell you, I was in the same place you are a year ago. But our experiments, our technical bases at this point does not support it. And if we wanted to put that, the choice that, in my opinion -- this is personal opinion we have -- is to design or develop or use an existing methodology that the uncertainty. We tried that. We tried in the paper that Francisco is talking about, and somebody told us, oh, boy, you're starting a Ph.D program.

MR. APOSTOLAKIS: Heaven forbid.

MR. NAJAFI: Well, to put it exactly, somebody told us, I didn't know SAIC gave PhD's. I said, “We don't.”

MR. APOSTOLAKIS: I think we have resolved this. Said, do you have a question.

MR. KHALIK: Yes. I guess I would like to ask about this unlucky user who doesn't make it through the funnel. And the question is how tight is that funnel compared to the expected ranges of parameters that one is expected to get in hypothetical scenarios?

MR. NAJAFI: Okay. I can tell you this in two parts. One, we have not tested that funnel, so we should do and we will probably do -- we have collaborative joint project we're doing at Nine Mile Point -- that would be a potential test case -- that we take those scenarios, run it through this funnel, and hopefully 95 percent will pass.

On the other side, I would say, that we started the finding of these scenarios with basically a range of conditions. If you recall, I said we created a library of nuclear power plant fire scenarios. Part of creating that was defining the range: how big are the rooms; how small are the rooms; what are the ranges of the ventilations. We went and collected information from a dozen plants that tell me, for example, what is the range of your ventilation in your main control room.

So we collected that, and we tried to map the experiments we have, which, as I said, this first funnel is the mapping of experiment to reality, and we didn't see hugely different things. There are exceptions in the power plants, like a ventilation shaft for an H-vac area, there is no very narrow long, long, long, long -- those may not pass.

But I expect 95 percent pass because we took these, checked it against this. There were no surprises.

MR. KHALIK: But it would be a good idea to document that just to see where we expect to be compared to this relatively well-defined range now of non-dimensional parameters in which you're saying okay, you can go ahead and use these models with the proviso that some of them are green, some are yellow, et cetera.

MR. NAJAFI: I completely agree with you that someday if we test that in some plant, we should document it and say where we stand on that. Thank you.

MR. APOSTOLAKIS: Now, are you done, Bijan, with the summary?

MR. NAJAFI: I'm done if you are.

MR. APOSTOLAKIS: No. I'm not done.

MR. NAJAFI: With me.

MR. APOSTOLAKIS: It seems to me that we have to discuss one or two things. So my understanding is that the current plans are for this cooperative work, collaborative work to develop a user's guide whose contents are to be determined? Okay. So the important thing is that this is not the end, what we see now is not the end, correct?

MR. DREISBACH: This will be the final document for the Verification and Validation. Another project will create another document completely.

MR. APOSTOLAKIS: Called user's guide?

MR. DREISBACH: Whatever we call it, that's what it will be. There is a concept of a user's guide, and that will be a separate document, a different tool, we'll say, than this tool.

MR. APOSTOLAKIS: Okay. There are a couple of things we have to do. One is to give advise to these people as to what they should present -- we have an hour and a half, I suppose -- yes -- what they should present to the full committee.

MR. DREISBACH: When Is that going to be?

MR. APOSTOLAKIS: October. And we are writing a letter.

MR. DREISBACH: A couple of weeks? Early October, right? First week of October?

MR. APOSTOLAKIS: Yes. And I would like to get the opinion of the members, at least the first impression as to where we stand. Now I don't recall this subcommittee reviewing this in an earlier stage. We never really reviewed this. Why? Why not?

MR. DREISBACH: We presented about an hour or two. The subsequent presentation today, we did a similar presentation last year in front of the Fire Protection Subcommittee subsequent to asking for a waiver for ACRS to review after a public comment period was complete.

MR. APOSTOLAKIS: But we never really had a meeting where you told us what you were planning to do, that you were planning to calculate those epsilons and this and that, so you never really got any input from us on that.

MR. BANERJEE: Some of that information was in the presentation.

MR. APOSTOLAKIS: Was I there? I don't think I was there.

MR. BANERJEE: I don't recall if you were there, but we --

MR. APOSTOLAKIS: You were already well on your way though?

MR. BANERJEE: We -- I remember clearly discussing --

MR. DREISBACH: Ready to go to public comment space.

MR. APOSTOLAKIS: Yes. You were ready to go to public comment, so the work had been done.

MR. DREISBACH: Yes. Work had been done.

MR. APOSTOLAKIS: What I'm saying is that --

MR. DREISBACH: But a very considerable amount of work was done after that meeting that resulted in this document. In other words, we adjusted somewhat the approach --

MR. APOSTOLAKIS: Well, in general, you know -- I know it doesn't help now, but, in general, it's a good idea for projects of this magnitude to have a meeting like this when you have a plan, but you hadn't started the actual work, because then you have the benefit of our comments, and you may or may not choose to use them. But now it's difficult.

Okay. So what should these gentlemen present at the full committee meeting which will also determine the nature of the letter?

MR. BONACA: It seems to me, you know, if I look narrowly of the objective of having V&V of fire models, they have done the job to do a V&V within certain contexts. Clearly, these are all matters that are very empirical, it seems to me, in general. And so therefore, you tend to have a very important -- very important that you match the physical test with the model that you're developing. And that's what you're trying to demonstrate. So you're really forcing the user to verify that you fall within a certain range because otherwise, applicability is questionable. So I think in the context, I would say that from a perspective of a fire protection engineer at a pant, this would be a very useful tool. It provides a lot of information.

Now I don't know at this stage of the game -- what is the regulatory use of the fire protection engineer at the plant. So, therefore, I can't comment on the usefulness from that perspective. And maybe there is still a step to be defined there as a regulatory product, like a reg guide that says how this can be used in support of some regulatory application.

From a PRA standpoint, clearly there is a step to be done, too. This is not usable right now. And I think again, however, it's more that you need an intermediate step, a regulatory step, or a definition of a reg guide that would define maybe further refinement of this work into some outputs that can be used as inputs to a PRA. I don't know. Certainly some other product in between that goes from this product to be used in the field on PRA.

So I would give two messages in the letter. I mean I don't know. You're not talking about the letter right now? Or their presentation.

MR. APOSTOLAKIS: Happy to receive all the input I can get.

MR. BONACA: it seems to me that, you know, this is a very good first step for a V&V of these products. And, you know --

MR. APOSTOLAKIS: The committee doesn't -- you remember, Mario, the committee usually doesn't like to say first step. So find other words.

MR. BONACA: Well, it's a big step. These are the fire protection -- you know, fire tools that are being used by the industry.

MR. APOSTOLAKIS: So it's not understood then that when one says I'm going to verify and validate a code in general that that person must make a statement regarding the uncertainty associated with the predictions of the code? They don't do that.

I mean what they did -- first of all, I do appreciate the magnitude of the effort and, you know, as their reviewers also commented, and today we heard this is the first time that the fire community, the fire safety community has undertaken such an effort to do a systematic job. But I think there is some incompleteness here that is really important.

MR. BONACA: Trying to understand, however, much of the incompleteness is something that should really be part of this versus something that needs to be done.

MR. APOSTOLAKIS: I understand that. But I mean they're asking us to approve this NUREG. So if we approve, it is published, and it's used. Now we can screen in three other places of the letter, but it's incomplete. The truth of the matter is that it will be a NUREG. Now people will use it. So that's the dilemma I'm facing.

I mean everything you said I agree with. I'm sure there are fire protection engineers that will find use -- and Bijan gave us good examples, I think, of doing certain things that will be quick, and maybe if it's conservative, you're off the hook and so on.

Anyway, I mean we don't have to resolve it right now but.

MR. BANERJEE: I have a comment. Looking at the title of this, you are promised more than you actually get, because it's not fire models in a broad sense. You really are doing the modeling of some part of the problem which has simply to do with the flow of the concentration fields and so on. Some of the most difficult parts of this model, which is the propagation of the fires, the actual heat production, all these things are simply taken from empirical database somewhere and stuck in here.

So I mean it's too ambitious to call it fire models. You're not validating that part of it. That part of it has simply been taken from some previous experiments. And so what you're driving this with are a set of experiments which were done historically and the cable fires were this, that fires were that. And a very large part of the uncertainty seems to me to lie in that, compared to what is going on here.

I mean, the heat release itself, it probably could be uncertain by 50 percent. I don't know what the number is there. You know? So compared to that uncertainty coming out of the fluid mechanics here is not such a huge amount. I'm not getting the sense.

MR. APOSTOLAKIS: This is what they're addressing, right?

MR. BANERJEE: Yes. What you're addressing is only the uncertainty in the fluid mechanics, which his great. I mean I really like that. You're precisely specifying the heat input. You've got very well-controlled fires. It's a very necessary step that you're doing this. So the uncertainty is coming out of -- I mean you've given a certain heat input over a certain period of time, et cetera, you've characterized this room very beautifully, got the emission coefficients, all that, so it's a nice piece of work, good scientific work. But it's too ambitious to call it fire models. I would say this is a submodel in a calculation.

MR. HYSLOP: Can I comment during this period or is this just you guys? I think that my understanding of the document was to verify and validate the fire modeling codes as existed, the FIVE, the EDF, those codes. And that's what they did. Now clearly some codes may use a heat release rate is an input, but that's the way those codes were developed. So I guess, from my perspective, the title is accurate, even though, you know, there were fire modeling codes that were validated.

MR. NAJAFI: If I raise my hand can I -- I would add to the second part of it, we specifically say for nuclear power plant applications that it's not only the scenario, it's the type of the practice. Because for better or for worse, for nuclear power plant practice since even the early days of Zion Indian Point that George was involved in, we defined the heat release rate of a fire. We did not leave it whether to the comp burn or whatever with the associated uncertainties, even if it's 50 percent.

MR. APOSTOLAKIS: We calculated it using the equation you showed.

MR. DREISBACH: But it becomes then specified in the fluid mechanics model.

MR. APOSTOLAKIS: Then it's input to the

code?

MR. DREISBACH: Right.

MR. NAJAFI: Yes.

MR. DREISBACH: Regardless of whether or not you calculated it based on that equation --

MR. APOSTOLAKIS: Calculated outside?

MR. DREISBACH: Yes.

MR. NAJAFI: So the fact that we account for the uncertainty of the initial fire size, the heat release rate based on experimental evidence is that's because how the practice in the nuclear power plant fire modeling has been done for the past 10 years, 20 years.

MR. BANERJEE: Perhaps it's a matter of semantics, but to me, the issue, when I think of fire, I always think of how it propagates, where it goes, all that sort of stuff. And this is not what you're addressing here. So in the sense of a fire model, it promises to anybody but maybe a very tiny group of people who know precisely what you mean, which might be --

MR. DREISBACH: Right. I think, though, the term fire model, from the beginning, is somewhat of a misnomer based on the way it has been applied.

MR. BANERJEE: Yes. It's not a fire model.

MR. DREISBACH: It's a smoke and heat transport model.

MR. BANERJEE: Yes.

MR. DREISBACH: That's how it's used.

MR. JOGLAR: And we are also validating selective capabilities of them. I mean maybe FDS does plume, but it does other things that are not within this. So calling it fire model may suggest that we're validating every single aspect of that where we have a list of 13 things that we are actually validating.

MR. BANERJEE: We're not accurate in the title I feel.

MR. APOSTOLAKIS: Since you started this Sanjoy, do you want to complete your thoughts?

MR. BANERJEE: Yes. This was one thought I had that you are doing part of the problem. The second thing I think is that given that you're doing part of the problem, you have information there which I feel could be helpful to present -- I don't know how much more work will have to be done -- but presented in a way so that we have a feel for also what these predictions mean in terms of uncertainties. I know you've not gone the full way, but you've already got a fair amount of data. When you call something green, when you call something yellow, that already gives you some guidance as to how accurate, because you're within certain bounds.

MR. DREISBACH: That was the idea.

MR. BANERJEE: And I don't see any harm in giving that guidance to your users. You know? You've already got part of the story. You haven't done what we would call best estimate plus uncertainty. For sure you haven't done that. But you've gone, again, part of the way. So don't sell yourself short on that.

MR. APOSTOLAKIS: And don't just send us to Reference 43.

MR. BANERJEE: Yes. Please.

MR. APOSTOLAKIS: Please don't do that.

MR. BANERJEE: Make a self-contained --

MR. APOSTOLAKIS: An unreviewed reference. You don't tell us what it's about. You say there are ways of doing it, go to Reference 43. I mean that's not for a NUREG. Are you done?

MR. BANERJEE: Yes.

MR. APOSTOLAKIS: Okay, Said.

MR. KHALIK: I'm not going to repeat any of the comments made by my colleagues, so there are two additional issues that I would like to see that came up during the discussion. One of them is the rationale for not using data from non-nuclear industry. The comment was made that these data were examined and were deemed to be either inappropriate or incomplete because of lack of quantification of uncertainties associated with the data. And the comment was further made that that assessment was not documented. So somehow a rationale for explaining why we haven't expanded the database to include data from outside the database that you've used would be very helpful.

The second comment that also came up during the discussion is that it would be helpful to provide the underlying bases for the specified non-dimensional groups and their applicability to the various models.

MR. NAJAFI: Can you repeat the second one?

MR. KHALIK: The underlying bases, I think the comment was made that these just fall out readily for non-dimensionalizing the Navier Stokes equations, and if that is really the case, then, you know, in some cases, you know, natural convection effects don't appear, and the question is why.

MR. BANERJEE: Well, I think they promised us a document summarizing either part of this document as an appendix or whatever, the choice of the non-dimensional groups instead of trying to read a whole handbook and try to get input into that, just summarizing how one arrived at these non-dimensional groups and why they're felt to be the ones that are important. They're not intuitively evident.

I mean you've got a fluid number, and usually fluid numbers have to do with gravity waves. So I don't understand how it actually arises other than purely empirically. So I'd like to know the rationale behind it. You know, fluid numbers are not normally thought of as internal waves or gravity waves, but why does it arise here? I'm not clear. Grashof I would have believed. You know? So we'd like to see that justification.

MR. APOSTOLAKIS: Now if I were you gentlemen, I would prepare for a presentation in October. Since we have a total of an hour and a half, you should plan on taking maybe five, fifteen minutes, no more than that. Because I am sure the other members will have questions, too. Now I think, and my colleagues here can jump in at any time, of course, I think you should skip other statements. We want to be transparent. We know that. We know what you want to be.

Go to these are the objectives of what we did. This is the result in my view, Table 3-1. Let me tell you what green is. We declare this as green because we did this, we had the U_c, we compared, and here are a couple of examples. We call this yellow plus for such a reason. A slide or two so the committee will understand what your bottom line is.

Then it seems to me you should address the issue of the user. We do this. We don't do that. We plan to do it in the future, or we leave it up to the user to decide. If you're clear on these things, I think you will have a very understanding committee. Like today, we really had to struggle to come to the bottom line. And also, please address specific comments like what Professor Abdet Khalik just said about, you know, the dimensionalized groups. There were other questions from Professor Banerjee earlier about the scientific basis of certain things. I assume you will address those. But I'm just giving you what I think should be the overall approach, because you don't have a lot of time.

MR. BONACA: The other thing that, you know, I will suggest, you know, regarding the not using information outside the nuclear. If I look at the test they took, they're so specific to nuclear. And I think empirically based on the models. I mean those are so empirical, too, that I can understand how they want to stay very close to the test. Maybe that's something that you want to say.

MR. APOSTOLAKIS: Yes, Bijan,

MR. BANERJEE: -- do it because -- it seems to me that that's the best justification that your test which was very specific to, for example, a switchgear room -- I mean they all -- and so, therefore, that's why you stayed with that test, you didn't go searching for outside tests of other nature, because it's so unique and so specific and so applicable to all the power plants in the U.S.

MR. NAJAFI: Do you want to also hear about something you raised this morning about these differences between the fire scenarios that are outside of the capabilities --

MR. APOSTOLAKIS: Absolutely. Yes. I assume that we took notes of those. Not just me. I think all of us heard this, but I don't remember all of them now. But I do remember that people had specific questions, and we agreed that you would address them.

MR. NAJAFI: In that presentation?

MR. APOSTOLAKIS: Yes. In that presentation. But it's really very important, it seems to me, within 15 minutes of your presentation for the committee to see your final result and why, why you got a yellow, what does it mean. Or whatever, green, no reds.

And another specific issue that bothers me is –– maybe you can go back and think about it a little bit -- is this intrinsic model uncertainty. You sort of dismiss it. And it's there. It's there in your calculations. Now when you get this U_{C} -- I'm still trying to figure out -- you know, intrinsic model uncertainty means that I will have some systematic overestimation or underestimation within some range. Yet the U_{C}, isn't that what it is? A bias, right, model uncertainty, you know, like FIVE-Rev 1. It tends to be conservative. It over-predicts, which is fine as long as I know it.

But the U_{C} has the implication that there is some randomness within this range that can be up or down, and I'm not sure that if you have intrinsic uncertainty that's correct. In fact, over a few of the slides you showed, the red curve was always above the measure, which tells me that there is really a tend to over estimate with some uncertainty. Okay? And would I know that by just going to your table? If you say yellow plus, I probably would. But in the green --

MR. NAJAFI: That's why we use yellow plus.

MR. APOSTOLAKIS: But these are the kinds of issues that I think we should spend some time talking about.

MR. NAJAFI: Yes. But the only thing I want to add to what you said is that I think there is more concern besides some of the examples that you said that is included or embedded in an uncertainty that a model prediction could have, just the model prediction. And that includes all the way from how model matches your scenario. Because all these models, as well all know, even the FDS, the most complex of all of these codes, the DDCFDs, they have to simplify the physics. They have to simplify it to solve it. And through that simplification, how much you deviate, whether it's in a steady state or the transient part of the scenario, from your fire scenario and actually what in reality will happen, it's too uncertain. There are so many factors.

MR. BANERJEE: If I understand it, your current model uncertainty is primarily driven by an input uncertainty?

MR. APOSTOLAKIS: Yes. That's what it was.

MR. BANERJEE: Yes. That's basically so --

MR. APOSTOLAKIS: Primarily Q dot.

MR. BANERJEE: Yes. Whatever. So that is leaving out, in a sense, what George, and I suppose others, call intrinsic uncertainty.

MR. APOSTOLAKIS: But they call it intrinsic.

MR. NAJAFI: Yes.

MR. BANERJEE: So in fact, when you couple that to the uncertainty in the inputs, that band would be larger, wider because of that?

MR. DREISBACH: That's why early on in the presentation we characterized this uncertainty as a tighter band--

MR. BANERJEE: Yes, I mean but you have to clarify what you're doing --

MR. DREISBACH: -- so we have a criteria that's --

MR. APOSTOLAKIS: But the question is, is it just larger, or has it also shifted? I think it's shifted.

MR. NAJAFI: That's why --

MR. APOSTOLAKIS: It moves up.

MR. NAJAFI: That's why I didn't disagree with that that is the intrinsic uncertainty. What I said is that there may be more input, more sources of uncertainty.

MR. APOSTOLAKIS: Absolutely.

MR. NAJAFI: There's a lot, and it's hard for me to tell always. I mean I used a good example, Kevin, if I may, that he -- he doesn't know even what I'm going to say -- is that there are these effects near affect --

MR. APOSTOLAKIS: Up to this point, right?

MR. NAJAFI: --the near affect and far affect. -- I mean these models and some of these predictions, the ranges of uncertainty varies even if you happen to be too close to the fire or too far from the fire, if the plume happens to be next to a ventilation. There are so many different things.

MR. APOSTOLAKIS: But the point is you -- I mean maybe you're already doing it to some degree -- you should sensitize the user.

MR. NAJAFI: Yes.

MR. APOSTOLAKIS: Maybe the intrinsic uncertainty is overwhelmed in some cases by the input uncertainty.

MR. NAJAFI: Yes.

MR. APOSTOLAKIS: I'm willing to accept that.

MR. NAJAFI: What, in my mind, we tried to do as knowledgeable people of the need of the fire modelers -- what I mean fire modelers is end users, some fire protection guy that starts using it, and people who developed the code and the theory all the way from Kevin to Jim Quintiere and Craig Beyler -- is that we put ourselves through that practice of using these numerics so that the end user can use a product that is much simpler to use.

So we went through that exercise of instead of developing a full blown uncertainty project for the fire models, for the CFAST for example, we went through this numerical exercise. And basically we jumped almost our uncertainty estimate into a color code. We did that intrinsic in a sort of a leap of faith. We said we look at these all attributes. We know these models. We know the physics. We see these, what they do. Some they're too far up, too far low, to the left, the time actually -- we even looked at the time. What if its time shifted? There's not, but it's time has shifted. So we collectively took that and we said in some expert panel thing, for lack of a better word, and said the uncertainty is green.

So because right now a method that is well-understood, well-accepted by everybody how to assess model uncertainty, we could not point our finger to it and say everybody will agree to that. So we went through a pseudo expert panel and, to us, that is a substitute for model uncertainty of this collective team. And, please, speak up if you disagree with that.

MR. McGRATTAN: I'll say it in a different way. The big picture, the big idea here is that each of these models is a collection of many, many algorithms. If we tried to go through each of the models and assess the uncertainty of each of these sub grid algorithms and so forth -- I mean you mentioned the k-epsilon parameters, we used the Smagorinsky coefficients, on and on and on -- that would be just an impossible exercise. So instead, we looked at the measurement uncertainty, uncertainty in the measurement of the inputs, uncertainty in the measurements of the outputs and these experiments, and use that as a guide or as a yardstick to assess -- this word intrinsic -- I think there's probably a better word -- to assess really what the uncertainty in the model prediction is by using the experiment instead of trying to get into the nitty-gritty of all these algorithms. That's the big idea here.

MR. APOSTOLAKIS: Okay. Thank you very much.

MR. BONACA: Just a question. Are you sure we have only one and a half hour?

MR. APOSTOLAKIS: It is usually an hour and a half.

MR. DREISBACH: It's my understanding two hours at the maximum.

MR. BONACA: It is two hours at the maximum I think.

MR. APOSTOLAKIS: Well, can you check? Not that it changes anything but -- well, I have a question for you gentlemen. Is the NUREG approved or not? And we have to say something in the letter. As is, should it be issued or not?

MR. BANERJEE: As is?

MR. APOSTOLAKIS: As is.

MR. KHALIK: If I were to vote now, I'd say no.

MR. BANERJEE: No.

MR. APOSTOLAKIS: Mario?

MR. BONACA: I don't know.

MR. APOSTOLAKIS: I don't know. That's fine. Okay. Anything else that anyone would like to say? Thank you very much gentlemen. Appreciate your presentations, and we will see you in a couple of weeks.

(Whereupon, the matter went off the record at 2:21 p.m., and back on the record at 2:47 p.m.)

MR. APOSTOLAKIS: Okay. The subject is NUREG-1852, Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire. I see Dr. Lois is there. You will start the meeting?

MR. IBARRA: Let me get a few introductory remarks. Thank you very much for meeting with us. My name is Jose Ibarra, and I am the Branch E for the Human Factors and Reliability Branch and the Office of Research.

Since this committee is assembled today, we thought we would take the opportunity to take about NUREG-1852. And the name of it is Demonstrating Feasibility and Reliability of Operator Manual Actions in Response to Fire. Now why do I say the name? Mainly, because I think you all have heard about this document, at least the technical content in the past. We did brief you when we were talking about this being a regulatory guide and we were talking about rule making in operator manual actions.

This NUREG has been released for public comment in the last few days and, of course, we will be before the ACRS to give a briefing once we get the public comments resolved. Today, we do have Dr.

Erasmia Lois from my staff to talk to you about the technical content. And we were supposed to have Sunil Weerakkody from NRR, but he has been called to do some sort of briefing to the commission, but I do have Alex Klein. He will talk to you about how this NUREG is going to be used in the regulatory process. Erasmia?

DR. LOIS: Okay. Well, thank you very much for the introduction. The first thing that I would like to note about the NUREG-1852 that this is a project of close collaboration of NRC staff specialists, specifically in Iran and our contractors, Sandia National Laboratories, Dr. John Forester and SAIC, Alan Kolaczkowski, and as I present to talk a little bit later, you will see that this is actually kind of a summary of insights and lessons learned and knowledge through the years by doing work on fire as well as on human performance.

In terms of overall presentation, I'll cover quickly the purpose, and then I will talk very briefly about the NUREG and present a summary slide. As Dr. Ibarra said, the purpose is to inform the committee about this activity. This is kind of a heads up and inform you about the plan to present the technical content in more detail after public comment and before we revise it and as well as request feedback at this stage of the activity.

In terms of background, when the rule making activity was going on for the Fire Manual Actions, we developed Draft Guide 1136 with the title Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire. And that regulatory guide was providing the technical basis for the rule making activity. However, the rule making was stopped. On the other hand, the NRC, through the exemption request, is going to help to evaluate the manual actions that licenses are or have been implementing to maintain and achieve -- maintain safe shutdown.

The reg guide, DG-1136, was providing the technical basis, and because of the NRC's need to evaluate the human actions, we decided that we should retain the technical work performed as a NUREG. The objectives of the NUREG-1852 are to provide technical bases, as I said, and in actuality, to be used as a reference guide by the NRC staff reviewing licensee submittals. And that aspect is going to be covered in detail by Alex.

MR. APOSTOLAKIS: Erasmia, can you remind us why the rule making activity was stopped?

MR. KLEIN: Dr. Apostolakis, I have a slide on that, and I'll briefly talk about that. But to answer your immediate question, when we briefed the committee, I believe it was in November of last year, we had indicated to you that the proposed rule was withdrawn because it would no longer meet the efficiency and effectiveness goal of the NRC because the comments that we got back from the industry were that they would still submit a large number of exemption requests as the proposed rule was written in the form of the proposed rule due to some issues.

MR. APOSTOLAKIS: Now I remember. Yes. Thank you.

DR. LOIS: The scope of the NUREG, it does not address actions needed after control room evacuation, and also, it does not stop at the defense and depth criteria that are actually recommended in Appendix R of Section III.G.2. In terms of status, it has been released recently. And as I said, we are going to brief the ACRS, and we'll finalize it by next spring.

MR. APOSTOLAKIS: Do you also plan to issue a regulatory guide or just the NUREG?

MR. KLEIN: No. We're in the process. We have a regulatory guide in existence right now. It's Regulatory Guide 1.186. We're in the process of revising that regulatory guide. And as I understand it, there is going to be presentation in the near future, I believe it may be as early as next week, on a series of regulatory guides that are undergoing revisions and at a high level. I think that they'll introduce to the committee the revisions to Regulatory Guide 1.186 and dat some future time come back to you with the details.

MR. APOSTOLAKIS: And this regulatory guide would rely on this NUREG?

MR. KLEIN: That's correct. The regulatory guide will refer to it.

MR. APOSTOLAKIS: One point eight six you say?

MR. KLEIN: One point one eight six.

MR. BONACA: If I remember, the bone of contention was the automatic fire suppression, right?

MR. KLEIN: That's correct. There were actually two. The condition to have automatic fire suppression as required by the existing rule, III.G.2., and the time margin was also an issue that the industry had commented on.

DR. LOIS: The approach, like the Regulatory Guide 1136, it's a deterministic approach. It builds on existing, as I said, knowledge and experience gained through the years by performing and developing guidance for human performance issues and also doing fire inspections and other kinds of inspections, very much on human factors related guidance and industry standards. In addition to the NUREG builds on a review on insights and knowledge gained by reviewing PRAs, hybrid PRA reports, et cetera, which address the availability aspect of human performance.

So in many respects, the criteria that are documented in NUREG-1852 explicitly document the criteria that have been used so far by the staff for various types of inspections of human performance, including fire.

Now in terms of risk-informed approach, because of NFPA 805 and the use of it, we plan to collaborate with EPRI to develop an HRA methodology that it would be used for fire-related HRA analysis.

MR. APOSTOLAKIS: But that will not be deterministic, I hope?

DR. LOIS: It will be risk-informed.

MR. APOSTOLAKIS: HRA?

DR. LOIS: HRA.

MR. APOSTOLAKIS: So, now -- I hate to say this -- the agency has three methods for addressing human performance: NUREG-1852 and SPAR-H.

DR. LOIS: I think SPAR-H or ATHEANA or any other method are methods that were developed primarily on a full-power PRA analysis and fire is not a measured part of it, so the hope is, and I'm going to -- Bijan is here -- the hope is that the industry and the NRC agree on a methodology and then expand it and develop it so that it will address fire regs.

MR. APOSTOLAKIS: We're talking about fires now.

DR. LOIS: Yes.

MR. APOSTOLAKIS: But what I'm saying is that having three different methods, all NRC methods, is probably not a very happen state of affairs. For example, when we had the subcommittee here last December, I think it was, talking about time and how to handle it and so on, there was a very strong argument made by Dr. Gareth Parry that in most cases, the time available is much larger than the required to perform an action, so we really didn't need to go to a time-focused HRA method. And I see here that's what you're doing. You're making sure that the time available is much larger than the time required to do it plus some margin.

But my question is why can't we use 1852 to replace all the HRA models? By reading the report, I get the impression that everything is fine. You estimate five minutes. You double it. You compare it with the time available. You can say I'm happy.

MR. KOLACZKOWSKI: This is Alan Kolaczkowski, SAIC. First of all, let me make one distinction. You're statement is correct about the three methods, but this is purely in deterministic space.

MR. APOSTOLAKIS: Understood.

MR. KOLACZKOWSKI: Okay. Just as long as that's understood. So while there are three, ones an apple and the other two are versions of oranges.

MR. APOSTOLAKIS: But the apple seems to be solving a lot of problems, so maybe an apple a day makes the oranges go away.

MR. KOLACZKOWSKI: You pose a very interesting questing.

MR. APOSTOLAKIS: Thank you, Alan.

MR. KOLACZKOWSKI: Okay. I will say this. If in the risk-informed world you do want to have a better idea of what drives human performance than to just dump everything into one thing called time, you just have to at least ask the question, will that help us learn and how to improve, or are we just trying to get a number, or in this case, are we just trying to pass an acceptance criteria and we don't really care why the thing might take 27 minutes versus 25 minutes.

MR. APOSTOLAKIS: But I read very carefully the Appendix to this report, which I believe you and John probably had something to do with.

MR. KOLACZKOWSKI: I'm sure.

MR. APOSTOLAKIS: In fact, you are the authors I believe. And you do take into account when you put the margins these uncertainties. Again, the question in my mind is either this document is not appropriate because even with the margins as you just said, there is still a probability that we'll make a mistake. Or if this document is okay, I don't need ATHEANA and SPAR-H, I don't need anything else. All I have to do is find the available time from this gentleman, the thermohydraulicist, then ask the operators how much will it take you to do this. And they would say 3-1/2 minutes. I double it. I triple it. I'm still within the limit and I'm happy. So it seems to me there is a conflict here. Either the deterministic method is correct or it isn't.

DR. LOIS: Can I answer that?

MR. APOSTOLAKIS: Of course.

DR. LOIS: I think in this deterministic space, for those actions that the time is not adequate, are not going to be approved. So you can conceive cases where potentially you have a task that would need to be accomplished with many consecutive actions, people would have to communicate, go here and there, those instances, unless there is a true justification that there is -- you know, if it takes half an hour, you have an hour already, and, yes, we are going to have the crew on shift, and yes, yes, yes, yes, yes, the deterministic criteria provided here shows a lot of the uncertainties that we're addressing in human reliability.

When we do a human reliability, we don't know -- there are no regulations that would ensure that the best crew is going to be on shift, or it won't happen at 2:00 in the morning. And we're dealing with those kinds of aspects in a probabilistic approach while here, a priori, we assume that are going to be in place and, therefore, they're not unknown anymore. So in a way, we have addressed several of the uncertainties that we're dealing with in human reliability through this establishment of the criteria and working in deterministic ways.

MR. APOSTOLAKIS: Well, I must say that I don't quite agree with that, because this report has a very detailed discussion of the various uncertainties. And, you know, it goes into things that are very nice actually, that the crew may be a mixture of very competent people and novices and so on. And then it argues, you know, that why the margins that are proposed are appropriate. In fact, I see here factors that cannot be created in the demonstrations have to be taken into account, the operators may need to recover from or respond to unexpected difficulties, there will be variations in fire and related plant conditions, so there is really a very nice discussion of all the uncertainties and what the demonstration can or cannot demonstrate. Typical and expected reliability among individuals, my goodness, look at all these bullets. And then, bang, here is a margin that takes care of all of this. So why do ATHEANA then?

MR. FORESTER: I'm John Forester. A couple of comments where I think this may be a special case. One is the diagnoses for most of these types of actions are very simplistic in a sense that many of them are preventative actions so that the cue for the actions is simply the existence of a fire. So it's a very benign kind of diagnosis in many cases.

And secondly, even though Gareth Parry is probably correct in a sense that there is a lot of time available for many of these actions, there are cases where there is time pressure, and there could be more complex diagnoses involved. So in those particular kinds of situations, I'm not sure this type of model goes quite far enough.

MR. APOSTOLAKIS: Yes. But I mean if we are approving a model that is applicable to fire conditions, which, you know, are not a simple thing, and it's a deterministic model, either it is adequate or it isn't. Now the approach here is fairly similar to the ATHEANA approach or scenarios in the sense that you have the expected sequence, and then you try to think of variations. You don't call it that, but it's really the same thinking. But at some point it seems to me that the NRC or the management should think about the whole issue of human reliability and what are we doing as an agency. I mean having one model in Idaho, two models here really different, we have to settle on something at some point. And then we have EPRI with its own model. So I don't know what to make of all this. I mean we really need some sort of coordination. Alan, you want to say something?

MR. KOLACZKOWSKI: Yes. Alan Kolaczkowski. I guess the only think I would add is that in a way, I view this as being the same thing as -- think where the agency was prior to risk-informed regulation process. We had deterministic criteria that we believed -- if we had, you know, single failure proof, a certain amount of redundancy diversity had to be met, et cetera, et cetera, those were very explicit criteria, and if the plant was designed that way, at least, even if we didn't really say this, in theory, we thought the risk of a nuclear – of a severe accident will be low.

Now came along the PRA process where then we actually assigned -- we built logic models and built databases, et cetera, and said well, what is that residual risk. And in a couple of cases, we actually found out our belief that we had, by using single failure criteria, et cetera, we had kept the risk low. We said, hmm, maybe we do need an additional ATWAS rule, maybe we do need an additional station blackout rule, because there's a few holes there that we hadn't quite handled. I view this as the same. If you're going to remain deterministic space, that in order to handle these uncertainties, just as we had uncertainties about well, how much redundancy should we have, is single failure criteria enough, or do we need a double failure criteria. We made a decision and we moved on in the regulations.

Here we're making a decision. We're saying we're going to use time as a surrogate to capture all these other things. We believe if you've done that, that the risk of this manual action not being reliable will be low. But until you then actually do HRA modeling, through whatever methods, CPDT or ATHEANA or whatever, can you really say, so what is that residual risk that remains, and in fact does this rule do what we think we want it to do. I just see that that's the parallel. I don't know if that helps or not.

Now it doesn't address your question of given you decide to do NFPA 805, and you're going to do an HRA, why do we have 40 different HRA methods out there. I realize it doesn't address that question.

DR. LOIS: And I hear it will be in a case where the industry and the NRC hopefully will agree on the methodology at least for --

MR. KOLACZKOWSKI: Yes. At least the fire. We're actually going to try to have industry and the NRC agree on a method.

MR. APOSTOLAKIS: So you are on your way of having a collaborative agreement with them?

MR. NAJAFI: This is Bijan Najafi again. I just want to caution that this collaborative project has multiple steps to start and kick off a project, and we are in a planning phase of this project at this time. So other things need to and should happen before we actually put pencil to paper start of next year. It is critical to the industry. I guess we recognized that this is an important piece after we finished our previous work. Because of the manual action, because of the PRAs that are being done, this is an important critical piece. But still there are steps that have to happen before we can actually start. I just wanted to make that clear. Thank you.

DR. LOIS: Me being on the optimistic side, I'm saying it --

MR. APOSTOLAKIS: So this NUREG is for licensees who remain in the deterministic domain?

MR. KOLACZKOWSKI: They're not going to do 805. They decide they're going to stay with Appendix R.

DR. LOIS: It's not for the licensees.

MR. KOLACZKOWSKI: That's what this NUREG is for.

DR. LOIS: This is technical guidance for the NRC staff evaluating the licensee applications or requests to have manual actions as a means of maintaining how shutdown --

MR. APOSTOLAKIS: The thing is that I'm

afraid that your licensee will come in her with 805 and will say there that they're using this to convince themselves that their risk is low when it comes to manual actions, they don't have to do an HRA because it will be approved. And it will be very difficult to say well, gee, this was really meant for the other guys, not you.

But anyway, I think I made myself clear that we seem to be going in many different directions in the HRA area as a community, not just NRC. Because also the HCR, ROE, and the other -- what is the name -- the CBDD that the industry is using -- I mean I had the chance to look at it more carefully. It seems to be a reasonable thing, too.

So at some point, we have to converge it seems to me. We really have to converge.

DR. LOIS: I just want to remind the committee that we have initiated what we call the bench marking study which would allow us to understand the method's strengths, limitations, compare them in a deeper sense than what we have done so far with the good practices and the evaluation of the various methods with respect to good practices.

MR. APOSTOLAKIS: That's good.

DR. LOIS: And so we're getting there.

MR. APOSTOLAKIS: Okay.

DR. LOIS: We have steps to get there.

MR. KLEIN: If I could just emphasize the use of this NUREG, which I'll talk about in my presentation. It is for the NRR staff to use if and when we receive these exemption requests that the licensees have indicated that they would submit to us. And it's for those licensees who are under a deterministic licensing basis today.

MR. APOSTOLAKIS: But conceptually, it creates a problem.

MR. KLEIN: I understand.

MR. APOSTOLAKIS: A lot of the stuff we're doing is driven by legal requirements, but this committee has to point out the logical inconsistencies. Let me speed it up for you.

DR. LOIS: Sure. Well, probably most of the slides will not be needed to be covered. Just quickly, the NUREG has both visibility and reliability criteria, and it's two parts. One documents the criteria and why we have -- what is the technical for bases for those. And then guidance for implementing it.

In terms of difference with the reg guide draft guide 1136 is the fact what we've said before.

That for a time margin, we were recommending in the draft reg guide a factor of two, and we're not doing it here. But we insist the NUREG requires extra time, but then there are various methods how you can demonstrate extra time, and the licensees would have to justify their method and why that time is adequate. And the change was done because of commission direction and, I guess, comments on the draft reg guide.

These are the criteria. I don't have to size them. In terms of feasibility, probably it's worthwhile to mention that an action is considered feasible if it can be shown that it can be accomplished within the estimated time available, and the estimation comes from analysis performed, and in that estimation the criteria required to have taken into consideration uncertainties that are fire-related such as nature of the fire, fast, slow, et cetera. Also to be taken into consideration is the time that it would take to diagnose the event. And in a nutshell, the last criterion is to perform demonstrations. And, therefore, the estimated time has to be compared with the time that the demonstrations showed that it would take and make sure that the estimated time is large.

Now, licensees can come in and say that we use conservative estimations and, therefore, our estimations envelop all of those uncertainties. In those cases, they would have to provide the justification on how these are enveloped. In terms of reliability now, we address more uncertainties with respect to t--

MR. APOSTOLAKIS: Excuse me. All these estimates come -- I mean if I'm a licensee and come to you -- and you have a couple of examples here -- and say -- yes, I follow your diagram, and I estimate it will take me a minute and a half to do this manual action, does the NRC take that and accept it, or they have to actually show people running to do that in a minute and a half? What is the rule of the game here.

MR. KLEIN: From an NRR [perspective, when we review license amendments and exemption requests, this information, of course, provided such as you noted, if the information needs to be clarified, needs to be substantiated, we will go – and it has not already done so in the submittal, we will go back to the licensee to request additional information. Would we ask them for a demonstration? That's hard o say. I think it depends on the exact exemption and the conditions under which they're requesting it. There might be situations when it's a very clear simple operator manual action, and the staff may or may not ask for a demonstration. If it's a complicated one, again, it depends upon the comfort level of the reviewer also. And he may or may not ask to have the licensee demonstrate to him or her that the action can take place in the time estimated.

MR. APOSTOLAKIS: The word demonstrate is used a lot in the document, and I thought it meant that they would actually have to do it, and you would be observing it, but you are saying no.

MR. KLEIN: We may or may not observe it. I think that the criteria does require the licensee to demonstrate that he can, because the licensee otherwise cannot estimate the time that it would actually take to perform the operator manual actions. Whether the staff would actually observe it, because we're at headquarters, again, we would most like likely not directly observe it. Again, I would have to go back to an example where if the situation does warrant it, we may request that of the licensee, but I don't, offhand, see that at this point.

DR. LOIS: So although we have a criterion for the licensee to be able to demonstrate the feasibility and reliability of the action, that doesn't mean the NRC is going to ask the licensee to demonstrate every action that they are doing.

MR. KLEIN: Right. Through our Reactor oversight process --let's assume that the licensee has been granted the exemption request. Through the Reactor oversight process, an inspector could go in and see the licensee, and in the process of that inspection, could ask the licensee to demonstrate the feasibility and reliability of their operator manual action through a demonstration, in other words, through a walkthrough with the inspection and demonstrate to the inspector that the timing is as indicated in the license amendment submittal.

MR. APOSTOLAKIS: But it may be very difficult to create fire conditions. I mean environmental affects, so I don't know what kind of demonstration that would be.

MR. KLEIN: Oh, absolutely. It is very difficult. We have the same situation with fire brigade drills today, same thing. Licensees do their best in terms of simulating the conditions for fire brigade drills, and I see this as a very similar situation. And John and Alan may be able to elaborate on that for me, but I believe that in terms of the environmental conditions and so forth, I think that's why we have the time margin built in, because of those uncertainties.

MR. APOSTOLAKIS: The main message I get from this NUREG is that whatever the estimated time is, you double it. Essentially, that's what you say. --

DR. LOIS: That used to be the case for the draft regulatory guide, and we have that included as an example, as one way for the acceptability for the time margin. But it doesn't mean that licensees would have to follow that example.

MR. BONACA: You know, time is not the only issue here, however. I mean what your concern -- I mean even if you were observing an exercise, you're measuring the time, you're presuming that everything will work that way that they've developed in the scenario. In reality, what you're concerned about is fire-related issues. You may have a man down that is burning or whatever and, you know, are you considering events like that? You have to. And that will affect the time in a way that is more difficult to evaluate.

MR. APOSTOLAKIS: That's why they double it.

MR. FORESTER: John Forester. Could I comment, please? I think the guidance suggests that they actually conduct a demonstration if they want to take credit for the fire manual action, so the intent is that they would conduct a demonstration, and they would try and simulate as many aspects of the actions as possible which means the diagnosis and what it takes to implement that. And to the extent that they can simulate fire effects, that would be a good idea. But the goal then is to get a -- and, you know, obviously under -- if they're at full power, they may not be able to open certain valves that may be required in the case of the fire, so they have to estimate certain aspects that’s involved in conducting the demonstration.

But at the end of that, okay, they've demonstrated that they can carry out this action and do all this stuff, with some estimations along the way, in a certain amount of time, and then at the end of that, then the consideration is that but there has to be some extra time, again, to cover the factors they couldn't simulate, like someone's down, there's water on the floor. That's the things that are to be covered by the extra time. But they need a basis to establish from the demonstration to be able to then take these other things into account and figure out how much extra time they need.

MR. APOSTOLAKIS: Well, the extra time it seems to me is really guidance from you, the margin. That's why I say that I get the impression that you're really recommending doubling the time.

MR. FORESTER: That's what we started with was suggesting factor two based on the process we used, but the notion was is that maybe in all cases, that wouldn't be necessary to have that level, that large a factor. But, again, the main thing is for them to consider all these other things that might go wrong that they couldn't do in a demonstration, and they want to make sure they do have enough time to cover those aspects, whatever that time needs to be. If they do that analysis and look at all those issues, then whatever time, they need to make sure they have enough.

MR. KLEIN: I think the discussion of the time factor of two in the NUREG I think was an effort to preserve the resources that were expended and the expert elicitation panels work done as part of the draft reg guide. It is not in there as a hard and fast criterion for the NRR staff to use to say to a licensee your time margin shall be two times. It is not.

MR. APOSTOLAKIS: I know it is not intended to be, but I mean it seems that that's roughly what would be an acceptable margin.

MR. KLEIN: I think --

MR. APOSTOLAKIS: If a licensee comes to you and has multiplied the estimated time by 1.2, I can see the reviewer saying, "For heaven's sake, you know, it seems that two is the appropriate number and you go down to 1.2, why?" I mean there will be a lot of discussion, but I appreciate that's something that's a subjective judgment.

MR. KLEIN: And certainly two is not a maximum either. I want to emphasize that, too. And I think that the commission, in their response back to the staff when we went out for the proposed rule, made a very similar comment in their SRM back to the staff.

MR. APOSTOLAKIS: Yes. Okay.

MR. KOLACZKOWSKI: Alan Kolaczkowski. I guess, just for the record, yes, I want to make sure it's clear. This does not recommend even the factor of two.

MR. APOSTOLAKIS: Yes.

MR. KOLACZKOWSKI: And if a licensee came and said, well, I multiplied it by 1.2, hopefully the submittal would say we think this is appropriate because to the best of our ability to measure, estimate, whatever, those uncertainties and their effects, we think we can justify, we will show you why we think just a multiply of 1.2 envelops those. And if they can provide adequate justification in the view of the reviewer, than that's going to be good enough.

DR. LOIS: So we have criteria for environmental factors. I don't think I should -- unless the committee has any questions on these -- equipment functionality and accessibility, availability of indications, capability for communicating during a fire event, the fact that portable equipment needed and personal protection equipment needed, criteria for those. I'm just skimming through. Unless you have any questions, I don't want to --

MR. APOSTOLAKIS: I do.

DR. LOIS: Yes?

MR. APOSTOLAKIS: It seems to me that what a lot of this report does is tries to figure out scenarios, possible performance-shaping factors and so on, and ATHEANA does this very well. Why didn't you bring some of the ATHEANA methods here?

The first part of ATHEANA with scenario development has nothing to do with risk, so it would be very helpful, it seems to me, to bring some of the ATHEANA methods to this.

MR. KOLACZKOWSKI: Well, again, we didn't -- we wanted to keep this in deterministic space. We don't want the licensee to provide a submittal where they've done some ATHEANA analysis.

MR. APOSTOLAKIS: But ATHEANA is --

MR. KOLACZKOWSKI: But if your point is that we sort of think along the same lines of an ATHEANA or even SHARP-1 or whatever that gets into investigating what's important, what are the important PSFs, whatever, you could say that's already inherently been done, and the result is we think these 11, or whatever it is, criteria capture, if you will, in HRA terminology, the PSFs that would be important for manual actions.

MR. APOSTOLAKIS: Yes. But I mean it seems ATHEANA is already in existence.

MR. KOLACZKOWSKI: Yes.

MR. APOSTOLAKIS: And it would help to bring that in here and also avoid creating this impression that we have three different ways of doing things.

MR. KOLACZKOWSKI: Okay.

MR. APOSTOLAKIS: But ATHEANA's approach for determining scenarios, I think, is its strength, and that would be very useful here. I'm not saying you're not doing it, but I think it would be very -- and also you have the various possibilities in text form, using eventries would be a much nicer way to display them. Let's see. There was something else.

Now the experts, are we going to talk about the experts?

DR. LOIS: No. I was not planning to cover that. I mean how we did the expert elicitation to come up with this margin of two, I'm not prepared. If --

MR. APOSTOLAKIS: Yes. But if I raise questions, are you guys going to answer them?

DR. LOIS: Sure. Just close the --

MR. APOSTOLAKIS: I'm sorry? Yes. If you're done, you're done.

DR. LOIS: Okay.

MR. KOLACZKOWSKI: I think we're done basically -- Alan Kolaczkowski -- I think because -- as far as all the other criteria go, and I don't want to absolutely speak for industry, but I think the indication is that industry and NRC are not at odds on all the other criteria, maybe with the exception -- I mean there's still a little discussion about the demonstration and whatever. But other than that, I think, yes, they all recognize you got to have cues to even know to take the action. You got to have the equipment available. You got to have communication so you can talk. I don't think industry and NRC are at odds at all on most of the criteria. That's why I wanted to spend a little more time revisiting the time margin stuff. And, again, the expert panel stuff, the factor of two that you find in the Appendix is there only as an illustration and not something that we expect the licensee to duplicate or even use for that matter if they choose not to.

MR. BONACA: I mean, if I remember, again, the requirement still is that they operate -- that the plant will have fire manual action -- I mean automatic fire protection, right? These are exemptions that the licensee wants to have? I mean I don't want to put --

MR. KLEIN: That's correct. If a licensee wishes to use an operator manual action in lieu of the protection requirements under III.G of Appendix R, III.G.2 which requires -- I'm sorry?

MR. BONACA: Which is automatic detection and suppression?

MR. KLEIN: When you have a situation where you have redundant trains in the same fire area, and you have one hour fire wrap or 20 feet of separation, the regulations today require licensees to have an automatic detection and suppression system in that fire area, yes.

MR. BONACA: And now they won’t take an exception or try?

MR. KLEIN: If a licensee wants to come and in lieu -- for example -- I'll give you an example -- in lieu of a one-hour fire barrier -- no, let me withdraw that. Actually, let me use the example of a three-hour fire barrier. Right now, the regulations under III.G.2, if a licensee has redundant trains in the same fire area and has one of those trains wrapped with a three-hour fire barrier but now wishes to remove that three -- or no longer take credit for that three-hour fire barrier, that licensee might want to come in for an exemption request. But, because he does not have detection and suppression in that fire area, and the staff believes that there is -- the consideration of defense in depth that the licensee needs to address is why the staff had put that in as a condition as part of the proposed rule. So --

MR. BONACA: Suffice it to say that it seems to me because they want to avoid this requirement, which I always felt was sensible, the burden is on the licensee to assure -- I mean I want to make sure that, you know, the requirement you make for demonstration, that human action is not only feasible but reliable, are strict enough, and they are not going to be negotiating now, you know, small fractions of time, but that's what's going to happen. That's what's going to happen, because now the whole issue has become reliable manual action, and we forget that really we are protecting certain vital areas where the redundant trains are running.

MR. KLEIN: That's correct. We have not, as of yet, as far as I'm aware, seen an exemption request since the proposed rule has been withdrawn, so I can't tell you at this point. I have no experience at this point. No database.

MR. BONACA: I understand that. I was just saying that as part of this, I would not have any hesitation to have very strict requirements on time available, because that's all you got --

MR. KLEIN: That's correct.

MR. BONACA: -- as an alternative to a sensible requirement of protecting an area with redundant trains. That's all you got is there, and they don't want to have automatic action.

MR. KLEIN: That's correct. That's why the staff had the position with the proposed rule that a licensee have detection and suppression in that fire area.

MR. BONACA: Right. But this is --

MR. KLEIN: You couldn't simply rely on an operator manual action to safely shut down your plant.

MR. BONACA: But you're doing this NUREG because the industry said, no, we're not going to do it --

MR. KLEIN: I think the NRR staff had --

DR. LOIS: You want to do why don’t --

MR. KLEIN: I can -- well, actually, I've done most of my presentation at this point. The staff had requested this research, the NRR staff did, because we wanted to have a consistent set of criteria for any future licensing amendments that might come in to the staff as indicated by the industry once we withdraw this proposed rule. So this is part of a tool, if you will, for the NRR reviewer to evaluate a licensee's amendment request for the use of operator manual action, along with the requirement that's currently in the rule today for detection and suppression.

Now that's not to say that a licensee can't demonstrate to us that the requirement for detection and suppression could also have an exemption request. Again, it depends on the specific situation.

MR. BONACA: I was pointing out that I

wouldn't be to shy to recognize that you are addressing the defense in-depth issue here and, you know, I think these time requirements should be strict requirements.

MR. KOLACZKOWSKI: No. We pointed out at that beginning of this presentation, the NUREG does not address the defense in depth part. You're going to have to go to something else to address the defense in depth part. The NUREG is purposely not addressing that part. It's only on the manual action itself.

MR. BONACA: I guess I was thinking that the time is the issue that provides some margin here so.

MR. KLEIN: Good afternoon. My name is Alex Klein. I'm here standing in for Sunil Weerakkody who is at a commissioner briefing currently. I am actually on rotation right now in the office of research, but I'm here as a representative of NRR and of Sunil to provide you with, I guess, of the planned use of this NUREG by the NRR staff. And, of course, we've discussed in some detail several of my slides already, so where that's the case, I'll try and proceed smoothly and quickly through those.

He's done a fancy way here. I see that. Sunil didn't tell me I have to press the button several times. Well, good for him. I guess he wanted to add a little big of a pizzaz to his presentation.

MR. APOSTOLAKIS: He always does.

MR. KLEIN: What I want to do -- and let me just press the button so you see them all. This slide is really to indicate to the committee that with respect to operator manual actions, there are a list of documents that we use. We, of course, have 10 CFR 50.48, Fire Protection, under which falls the reference to Appendix R.

We recently issued a regulatory issue summary, 2006-10, which basically outlines the staff's expectations with regard to Appendix R III.G.2 and operator manual actions. This (RIS) was issued following the withdrawal of the operator manual actions rule. And we mentioned this to the committee, that we would be issuing a generic communication to the industry, to reiterate and to re-emphasize back to the industry the compliance expectations for the use of operator manual actions under Appendix R. It also discussed some enforcement discretion policy changes. And it also discussed compensatory measures and corrective actions required by licensees who currently used unapproved operator manual actions.

I mentioned the Standard Review Plan, 9.5-1, and the revision to the RG 1.189. The RG revision 1.189, as I indicated to you, will be coming to the committee at some point in the future. We're also revising the SRP, of course, to match and be consistent with the things that we do in operator manual actions and in the circuits arena. And that's also a near-term activity. I believe that the revisions are ongoing right now.

Let me go to the next slide. Some of the supporting documents that we use, again, the RG. We have criteria for inspectors in the inspection procedure, 7111.05, Fire Protection. Actually, there should be a T at the end of that point 05. That's been in existence, I believe, since the year 2003. And that's used by inspectors to determine the acceptability of operator manual actions as a temporary compensatory measure while licensees go through their corrective action program and bring themselves back into compliance with the rule and their commitments.

We have, of course, the NUREG that we just talked about.

MR. APOSTOLAKIS: Is it RG 1.189 or 6?

MR. KLEIN: If I misspoke, it's 1.189. I'm sorry. If I said, 1.186, then I misspoke. It is

1.189.

This speaks to Dr. Bonaca's question with respect to defense in depth and so forth. The NUREG-1852 doesn't mention and doesn't obviate the need for detection and suppression. That comes out of a different document or set of regulations that we have. Of course, it's embedded in Appendix R III.G.2 as I indicated.

We talked about this next slide, RG 1.189, with respect to the time margin. What we're emphasizing is that, again, it speaks to this defense in depth issue that replacing certain fire protection systems or features such as a three-hour fire-rated barrier with an operator manual action we believe is typically unacceptable where redundant divisions required for safe shutdown are in the same fire area, unless, of course, alternative or dedicated capability is provided under III.G.3 of the rule which, by the way, also requires detection and suppression.

MR. BONACA: But you still have an exemption.

MR. KLEIN: That's correct. The licensees are free to submit exemption requests to the staff with respect to Appendix R. That's been a longstanding -- I believe there's a court case that actually provided that policy with respect to Appendix R, because it is a back-fit to licensees, the III.J and O sections of Appendix R.

With respect to the use of NUREG 1852, I think I indicated to the committee already that these are for exemption requests to be used by the NRR technical staff to use as a consistent way to review the use of operator manual actions by licensees in future licensing amendments. As I indicated to you, as far as I am aware, we have not seen any. But then again, I've been in Research for three months so.

MR. APOSTOLAKIS: The last sentence there is bothersome -- that they may use 1852 even in risk-informed evaluations. I thought you guys said no earlier?

MR. KLEIN: Let me take a moment if I could and take a look at Sunil's handwritten notes here.

DR. LOIS: Well, qualitative insight is needed. Well, this is supplemental information.

MR. APOSTOLAKIS: I don't know what the qualitative insight is. I mean what if they come in and say, look, we calculated all these times, we added the extra margin you guys want? They're okay.

DR. LOIS: But it would be risk-informed approach.

MR. APOSTOLAKIS: Allowed in a risk-informed environment. In other words, they may say here is a sequence of events in my fire PRA. I calculate the probabilities of the initiator and other things, and here is a manual action of which I will assume has a probability of zero for failure, because I did what NUREG-1852 said for a very low probability of failure. So the probability of a sequence is everything else. That obviates the need for an HRA.

MR. KLEIN: It may very well with respect to a qualitative evaluation. And I think that's what this bullet is intended to convey through a qualitative evaluation.

MR. APOSTOLAKIS: Thank you.

DR. LOIS: Another way to look at that could be that my performance shaven factors are the ones that are documented in the criteria in doing an x amount of reliability analysis.

MR. APOSTOLAKIS: But for the human reliability analysis, I have a whole method for finding these things. And I don't need to go to 1852 to get them.

DR. LOIS: But that method would tell you to look at these things that we're documenting in 1852.

MR. KLEIN: I think that's the intent of

this bullet.

MR. APOSTOLAKIS: Using it only for exemptions in the deterministic space, so that changes the rules of the game. So you're not asking for a Letter now?

MR. KLEIN: No, we're not. I believe that this bullet speaks to, again, a qualitative kind of an insight in a deterministic license amendment request.

MR. APOSTOLAKIS: Yes.

MR. KLEIN: I think that was the intent of this bullet.

There are a couple of limitations with NUREG-1852 that we wanted to convey to the committee. With respect to the first one, the criteria in NUREG-1852, again, is not intended to apply to main control room abandonment-type situations where the licensee would have to go to his remote safe shutdown panel. In other words, the timing and the considerations of the criteria as the licensee abandons the control room and goes to the remote safe shutdown panel, we do not intend to apply NUREG-1852 to that because of a previous generic communication under Generic Letter 8610 which addresses that question.

Again, the second bullet also doesn't -- again, we talked about the fact that it doesn't address detection and suppression. That requirement for detection and suppression, which the NRR staff believes is a defense in dept item is under the existing regulations of Appendix R III.G.2. And again, it's under the purview of the SRP RG 1.189. And it's reiterated in the RIS 2006.10.

MR. BONACA: But then if I apply for replacing my automatic actuation with manual action, don't I replace -- I mean manual action would not establish defense in depth. It clearly replaces that, right? It replaces the -- I mean -- I'm trying to understand --

MR. KLEIN: My understanding is that licensees would substitute an operator manual action for a fire barrier or a 20-foot separation for example. And that they would not substitute -- I can't think of a situation where they might substitute an operator manual action in lieu of a automatic suppression system. They may. And if that's the case, then the staff here would look at that defense in depth aspect or the loss of that automatic suppression system. We would then look at, okay, what is balanced against that. Is the licensee proposing to maintain a one-hour fire barrier? Has he adequately justified through a fire modeling, if you will, and so forth what types of fires might occur in there? Are they much less than the one-hour rating?

MR. BONACA: But my understanding is that there will be applications like that.

MR. KLEIN: There may very well.

MR. BONACA: Because, I mean some of them, by the current requirements, they'll have to install sprinkler systems in areas where they don't have them.

MR. KLEIN: That's correct. If a licensee currently today has no detection and suppression system in there, he most likely has three-hour fire barriers in that location right now.

MR. BONACA: Yes.

MR. KLEIN: And so the request would come in to use an operator manual action in lieu of that three-hour barrier. Now the staff would then look, okay, is the licensee proposing to provide detection and suppression along with that operator manual action in lieu of that three-hour barrier. If not, then the staff, of course, would look at the defense in depth aspect of the lack of detection and suppression in that area with only the use of an operator manual action. The staff is, of course, very concerned about the erosion of defense in depth in that situation.

MR. BONACA: What do you mean by they would look at it?

MR. KLEIN: They would consider that as part of the -- they would review that. They would evaluate it as part of that license amendment and determine whether or not the licensee has adequately justified whatever it is that they're asking an exemption for.

MR. BONACA: But NUREG-1852 will provide the base for this evaluation?

MR. KLEIN: NUREG-1852 will provide the bases for the operator manual action itself only. It does not provide the bases for the exemption from detection and suppression. That comes out of the Appendix R III.G.2 rule. And that is the last slide that I have.

MR. APOSTOLAKIS: Any other commends form the members? Staff? Thank you very much.

MR. KLEIN: Thank you.

DR. LOIS: Thank you.

MR. APOSTOLAKIS: So this is the end of the subcommittee meeting.

(Whereupon, at 3:47 p.m., the foregoing matter was concluded.)