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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

September 21, 2006

The contents of this transcript of the proceeding of the United States Nuclear Regulatory Commission Advisory Committee on Reactor Safeguards, taken on September 21, 2006, as reported herein, is a record of the discussions recorded at the meeting held on the above date.

This transcript has not been reviewed, corrected and edited and it may contain inaccuracies.

1 UNITED STATES OF AMERICA

2 NUCLEAR REGULATORY COMMISSION

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4 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

5 SUBCOMMITTEE ON RELIABILITY AND PROBABILISTIC RISK

6 ASSESSMENT

7 MEETING

8 + + + + +

9 THURSDAY,

10 September 21, 2006

11 + + + + +

12 The meeting was convened in Room T-2B3 of

13 Two White Flint North, 11545 Rockville Pike,

14 Rockville, Maryland, at 8:30 a.m., Dr. George E.

15 Apostolakis, Chairman of the subcommittee, presiding.

16 MEMBERS PRESENT:

17 GEORGE E. APOSTOLAKIS Chairman

18 MARIO V. BONACA ACRS MEMBER

19 SAID ABDET KHALIK ACRS MEMBER

20 SANJOY BANERJEE ACRS MEMBER

21 HOSSEIN P. NOURBAKHSH DESIGNATED FEDERAL OFFICIAL

22

23

24

25

I-N-D-E-X

PART 1

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

NUREG-1824

TOPIC/PRESENTER	PAGE
Opening Remarks	
George Apostolakis	4
Introductory Remarks	
Pat Baranowsky, RES/	5
Bijan Najafi, EPRI-SAIC	6
Programmatic Overview and Technical Approach	11
Bijan Najafi, EPRI-SAIC/	
Jason Dreisbach, RES/	
(Discussion of actual fire scenarios)	67
(Experiment description)	72
Experimental Uncertainty	131
Anthony Hamins, NIST	
Summary Results	185
Bijan Najafi, EPRI-SAIC/	
Jason Dreisbach, RES/	
Richard Peacock, NIST	

1 **PART 2**

2 **Demonstrating the Feasibility and Reliability of**

3 **Operator Manual Actions in Response to Fire**

4 **NUREG-1852**

5 TOPIC/PRESENTER PAGE

6 Introductory Remarks 241

7 Jose Ibarra/RES

8 NUREG-1852 on Fire Manual Actions 242

9 Erasmia Lois, RES

10 NRR Approach to Fire Manual Actions

11 Alexander Klein. 271/275

12

13

14

15

16

17

18

19

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

2 (8:30 a.m.)

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

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

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

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

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

1 *Register* on September 8, 2006. A transcript of the
2 meeting is being kept and will be made available as
3 stated in the *Federal Register* notice.
4 It is requested the speakers first
5 identify themselves, use one of the microphones, and
6 speak with sufficient clarity and volume so that
7 they can be readily heard. We have received no
8 written comments or requests for time to make oral
9 statements from members of the public regarding
10 today's meeting.
11 We will now proceed with the meeting,
12 and I call upon Pat Baranowsky of the Office of
13 Nuclear Regulatory Research to begin. Pat?
14 MR. BARANOWSKY: Thank you, George, Dr.
15 Apostolakis. I'm the Deputy Director in the
16 Division of Risk Analysis and Special Projects, and
17 we're pleased to be here today as we come to the
18 conclusion on what we think was a successful project
19 and one that's needed by both the NRC and the
20 regulated nuclear community as we move toward the
21 implementation of the National Fire Standard Act,
22 NFPA 805.
23 The particular work we're talking about
24 documented in NUREG-1824 involves the verification
25 and validation of computer models used in fire

1 analyses that both the NRC and the industry will be
2 using as we implement that standard.
3 The work that was conducted over a
4 several year period of time involved not only the
5 NRC as you know, but the National Institute of
6 Standards and Technology, the Electric Power
7 Research Institute and their consultant, SAIC. And
8 we have representatives from those organizations
9 today that will make presentations on this matter.
10 The NUREG was put out for public
11 comment, a 60-day public comment period earlier this
12 year, and we've addressed those comments, modified
13 the document and provided it to you before this
14 meeting.
15 That concludes my introductory remarks,
16 but I'd like to ask Gary Vine, the Executive
17 Director for Federal and Related Activities at EPRI
18 to give his introductory remarks.
19 MR. VINE: Thanks, Pat. I'd like to
20 start with a bit of history on the cooperation
21 that's gone on between EPRI and the Office of
22 Research on both fire and on all the other issues
23 that we've been working on together over the years.
24 Some of you have heard the history before. For
25 those of you who haven't, there was, under Shirley

1 Jackson's chairmanship, a major effort on strategic
2 planning and direction setting initiatives that
3 looked at a lot of facets of the NRC's operations.
4 One of the areas that was looked at was research.
5 And there were a number of concerns about the lack
6 of collaboration because of limited budgets and so
7 forth. And there was quite a bit of talk about
8 increasing international collaboration, but not a
9 lot of talk about increasing domestic collaboration.
10 So we discussed the options for doing
11 that, and it was decided that even though there were
12 some concerns about "independence" as a regulatory
13 agency, there was perhaps a way we could collaborate
14 significantly here in the U.S. between industry and
15 NRC if we could devise a way to keep the research
16 collaboration completely separate from regulatory
17 decision making.
18 That was the basis - the policy basis
19 for establishing an MOU between EPRI and the Office
20 of Research in 1997. The framework was signed off
21 that year with commission approval, and what it
22 basically says is is that the two organizations can
23 work together to collect the data necessary to
24 resolve issues for both industry and NRC, to do that
25 jointly and collaboratively, but that we're not

1 allowed to, as we work together, get involved in any
2 regulatory analysis or work that would lead to
3 interpretation of how the data should be applied in
4 regulatory decision making.
5 We simply complete the work on the data
6 analysis on the science side of the issue. The data
7 then goes to the program offices, NRR or NMS or
8 whoever the regulatory user of the data is. Our
9 data goes to the industry, nominally to NEI for them
10 to decide how they think the data should be used in
11 regulatory space, and our cooperation between EPRI
12 and RES ends at that point. We, obviously on the
13 EPRI side, will support any NEI and their
14 understanding of what we did. RES supports the
15 regulatory offices as they move forward. But the
16 benefit of this approach, of course, is that we're
17 starting with a common set of data and not arguing
18 about our data's better than your data or whatever
19 the holdup in the past has been. So it's a much
20 more efficient way to approach things, and it's been
21 very successful in a number of instances in getting
22 a joint understanding of the problem developed early
23 on before it gets into regulatory space.
24 Fire has been one of our best and
25 longest examples of historic success. As you can

1 see on the slide, the umbrella MOU was established
2 in 1997. There have been probably 20 different
3 addenda under that. There's about a half a dozen of
4 them that are active today, another half a dozen
5 that are still in existence but not as active in
6 terms of ongoing projects, and a number of them, of
7 course, have lapsed after completing the work.
8 The fire addendum was first drafted in
9 2001. It involved a lot of information sharing and
10 other preliminary activities that we worked on
11 together. One of the first major joint projects, of
12 course, was the Fire PRA methodology that was
13 briefed to you I guess it was last year and is now
14 being widely used throughout the industry and
15 throughout the NRC as the basis for moving forward
16 on transitioning to the new fire regulations.
17 That effort was truly a joint effort
18 where a team of EPRI staff, NRC staff, EPRI
19 contractors, and NRC contractors worked together to
20 produce a joint document. It went through all the
21 formal reviews on both the NRC side and the industry
22 side and is being widely used as I said.
23 The second major joint project that
24 we've undertaken is the one that you're going to be
25 reviewing today, which is our V&V of fire models.

1 This report is in draft form undergoing review.
2 It's actually been reviewed, I think, extensively on
3 industry and NRC side, and it's going through the
4 final stages, including your review. There are a
5 number of additional projects that we're
6 contemplating and/or have already agreed to
7 undertake in the fire area as a joint effort,
8 including fire HRA, low power shutdown, a fire
9 modeling user's guide and, of course, training is a
10 big part of this, because there's a lot of work that
11 has to be done to bring both industry and NRC staff
12 and their contractor reviewers up to speed on all
13 the work that has to be done.
14 So this has been a very successful
15 arrangement between NRC and EPRI in gathering the
16 data necessary for regulatory decision making and I
17 think in the case of fire, probably more than some
18 of the other areas. It has also been a successful
19 area in developing jointly the methods by which the
20 data would be used.
21 And so we hope to see more of this. We
22 sure appreciate the whole spirit of cooperation that
23 has existed on both sides as we've done al this work
24 together. Appreciate the support we've had from the
25 ACRS for this approach to getting the work done.

1 That's it. Thanks.

2 I'd like to, if we're ready to move on,

3 Jason and Bijan will introduce the other team

4 members that are here to present to you today.

5 MR. NAJAFI: Okay. I'm going to start

6 with a program overview.

7 MR. APOSTOLAKIS: Introduce yourselves

8 first, please.

9 MR. NAJAFI: My name is Bijan Najafi. I

10 have managed and worked on EPRI's fire protection

11 program for 15 years now, and I was the technical

12 lead for the fire risk requantification project and

13 this project as well.

14 MR. DREISBACH: My name is Jason

15 Dreisbach. I am the Program Manager for this

16 particular project in the Office of Research. I'm a

17 reliability and risk engineer, a trained fire

18 protection engineer. Bijan's going to start out the

19 presentation, and we'll be back and forth throughout

20 this first presentation that gives us a programmatic

21 overview and technical approach. And Bijan will

22 start.

23 MR. NAJAFI: We're going to start today

24 with this first presentation. I tell you what the

25 purpose of this front end is is that we will

1 introduce to you this project from a program level:
2 Why are we doing this, how we're going this, and
3 what is our intended product, I mean where do we
4 thing this product will fit, and what role does it
5 play. So this is part of setting the stage for the
6 technical discussions that come next. And I hope
7 that this background gives you an idea of what kind
8 of -- I mean sort of focuses the discussion of what
9 you might be interested to know about this project.
10 MR. APOSTOLAKIS: What are you asking
11 the ACRS to do?
12 MR. BARANOWSKY: Well after we finish
13 this meeting, I guess the plan is to go to the full
14 committee and get a letter endorsing the NUREG.
15 MR. APOSTOLAKIS: And then the NUREG is
16 not a regulatory document?
17 MR. BARANOWSKY: No.
18 MR. APOSTOLAKIS: So there will be some
19 regulatory guide later or?
20 MR. BARANOWSKY: Yes. I think Jason is
21 going to be showing you how this fits into the
22 regulatory picture.
23 MR. APOSTOLAKIS: Okay.
24 MR. DREISBACH: Yes.
25 MR. APOSTOLAKIS: Okay, Bijan.

1 MR. NAJAFI: Yes. That's something
2 we'll talk about, how this think fits into the
3 regulatory picture. But basically, to give you a
4 little bit of background is that -- I mean as you
5 well know, that over -- it's been over 10 years or
6 more that there is a move in the general community
7 and nuclear power plant and fire protection in
8 particular toward the risk-informed and performance-
9 based regulation. And among many things that that
10 kind of environment needs in a technical basis, one
11 is basically reliable fire model or modeling tools
12 that can be used.
13 And those basically tools can support
14 either existing regulation -- there's a number of
15 areas -- through the exemption request that has been
16 practiced that these models have been applied. On
17 the Reactor Oversight Process and SDP, these models
18 need to be applied. And under the NFPA 805
19 licensing basis, there is a place for the use of the
20 fire modeling. In order for these fire models to
21 basically fulfill that role, there is a need to
22 understand basically their predictive capabilities
23 within how they can address issues that are specific
24 to the nuclear power plant fire scenarios, and to
25 the extent possible, our intent was to be able to

1 quantify that predictive capability. So that's the
2 first objective. Next slide please.
3 MR. DREISBACH: Building on what Bijan
4 was talking about and the question that Dr. Hothlock
5 has asked about where this fits into the regulatory
6 framework, we put together this relatively simple
7 slide of where this particular document fits into
8 the whole regulatory framework. You see it down on
9 the lower right-hand corner where it says NRC-RES-
10 EPRI Fire Model V&V. This is basically providing
11 some sort of methodology document or, more
12 accurately, a technical basis document for this.
13 And it's in line with the PRA methodology that the
14 NUREG/CR 6850 EPRI 1011899 document. And as you
15 move up the chart, you increase the regulatory
16 decision making process, so the next level is the
17 standards that sort of point to the lower documents
18 as something that needs to provide some technical
19 basis. So you have the PRA standard on one side.
20 And you have the NFPA 805 standard, and then as you
21 move further up, you get into Reg Guide space where
22 now we're trying to implement the actual rule which
23 is at the top level.
24 Now you can add a lot of other things in
25 this diagram, like the Appendix R rule. You can

1 other Reg Guide, like Reg Guide 1.200 or Reg Guide
2 1.189. You can add other types of standards and
3 technical bases documents, like the SDP or other
4 PRA-type documents.
5 But this is sort of where we fit in, the
6 document that we're creating, how we fit into the
7 overall regulatory structure.
8 MR. APOSTOLAKIS: This is not -- Bijan
9 mentioned the significance of determination process
10 and so on. You are focusing on 5048-C?
11 MR. DREISBACH: That was the original
12 impetus for this document, because the standard, the
13 805 standard which is endorsed by the rule making
14 requires verification and validation of fire models.
15 However, models are also used in the other types of
16 analyses conducted under the existing rule making or
17 the previously existing rule making under Appendix
18 R, such as the SDP, the ROP-type frame PRA-type
19 analyses, or even the deviation exemption process.
20 We have seen applications that use fire modeling in
21 those situations even before we've had the
22 endorsement of NFPA 805. So this tool that we've
23 created can be used in the normal regulatory space
24 under Appendix R, but we focus a use or the impetus
25 originally was for use under NFPA 805 rule making

1 kinds of things.

2 MR. NAJAFI: So coming back to this

3 project, the specific one other question that may

4 come up is that one, there are enough V&V'S out

5 there. Why did we do this. Why did we take out

6 another V&V for this particular purpose. I guess

7 the answer to that question is that we wanted to

8 make sure to satisfy a couple of fundamental -- be

9 able to answer a couple of fundamental questions.

10 It's that the nuclear power plant fire modeling has

11 some attributes or issues that may be unique to

12 itself. We wanted to make sure that we basically

13 match those capabilities of those code to answer to

14 specific questions. Some may be the same. Some may

15 be unique. So we wanted to make sure how we can

16 match that. So that was one of the primary

17 objectives, and you will see it later on in our

18 presentation how it comes about through our

19 approach, the approach or the process that we took

20 to accomplish that.

21 MR. BANERJEE: Excuse me. Tell us a

22 little bit about what issues are specific to.

23 MR. NAJAFI: We'll come to that a little

24 bit later, but for example the issues that may be in

25 a atrium, in a mall, may be egress related, but the

1 issues we have is cable fires. We had issues in
2 switchgears. We have situations in power plants
3 that because of a more confined or compressed
4 geometries, the affect of calculated plume
5 temperature is more important than a smoke
6 migration, whereas in a hospital, generating smoke
7 and migration smoke may be more important to them in
8 a different environment. So we have to first
9 understand what our scenarios are, what our
10 attributes of those scenarios of interest are to
11 make sure that we validate for those particular.
12 And I hope that becomes more clear as we go, because
13 we talk about those scenarios.
14 MR. BANERJEE: You will talk about --
15 MR. NAJAFI: We will talk about those
16 specific scenarios and attributes that we're
17 interested in.
18 And the second piece that was somewhat
19 critical to us is that to the extent that it can be
20 supported by the data, we intended to be able to
21 come up with some quantitative measure of that
22 predictive capability. Why is that important to us?
23 Because in some of these cases we're facing, these
24 models are being used in what I call a post-design
25 as-installed condition. So it is -- we're trying to

1 evaluate something that is inexistent, it's not a
2 design.
3 So for us, how much margin we have and
4 be able to have an appreciation of that degree of
5 margin, it is important. Some of that margin may
6 be, for example, if we find that these are 25
7 percent off, whereas in the design stage, that may
8 not be important because you can deal with it in
9 safety factor. In an as-built situation, it may be
10 important. It may be important, that margin. So we
11 wanted to be able to characterize that accuracy to
12 the extent that we can in a quantitative way.
13 And also, I men because we selected a
14 number of codes that were mostly used in the
15 industry at the current time, in our industry, we
16 wanted to establish a process that, if necessary, in
17 the future can be followed for other models, other
18 codes, it's not limited to these experiments. So
19 it's more of a -- just as much developing a process
20 that it is to validate these particular codes.
21 MR. APOSTOLAKIS: At which point will
22 you tell us what predictive capability is?
23 MR. NAJAFI: We will hope to tell you
24 that during this. We will start by the end of our
25 basically technical overview. We will tell you

1 predictive capability by -- what I'm hoping is that
2 we tell you these are the scenarios that we are
3 interested in, these are the attributes of those
4 scenarios we're interested in. For example, the
5 attribute may be a plume temperature of an oil fire
6 in a small room, and then we define the predictive
7 capability meaning --
8 MR. APOSTOLAKIS: There is an important
9 table in Volume I --
10 MR. NAJAFI: Yes.
11 MR. APOSTOLAKIS: -- which you will show
12 it to us at some point?
13 MR. NAJAFI: Yes, definitely. In
14 Sections 2.3, 2.4, 2.5 and 6, those are areas that
15 we will discuss here later on today in maybe I would
16 say half an hour or no more than that, that it
17 basically says how do we define, how do we
18 characterize that predictive capability. That's an
19 important part, and we intend to discuss that today.
20 The next couple of slides is intended to
21 give you basically a picture of our recognition of
22 what we thought were the challenges of this project,
23 and how do we assemble this team to make sure that
24 we have the right team, because, I guess, like any
25 other project, the first challenge is to know the

1 problem you're facing. That's the number one
2 question. And if you understand the problem you're
3 facing, then you're second challenge becomes to put
4 the right team together.
5 MR. APOSTOLAKIS: That's my problem,
6 Bijan. I don't know what you're trying to get at.
7 What is the problem? You said 805, PRA's. Okay?
8 Now as far as I know, what we need there is the
9 probability distribution of temperature at some
10 point, or the time evolution and so on. So I don't
11 know that you actually do that.
12 MR. NAJAFI: In a PRA space, you have to
13 -- you have multiple -- you have a - conditions
14 generated by the initial fire. That is determined
15 by the size of the fire, location of the fire. We
16 have distributions for that. We deal with that.
17 And if you recall in the NUREG 6850 EPRI 1011899, we
18 described the issues or uncertainties related to
19 this inputs, the size of the fire. Once you get the
20 size of the fire, you have to analyze the
21 progression of the fire, how does the fire grow, how
22 big did it get, and what kind of damage it causes.
23 That is where the fire model comes into the picture.
24 That's just, let's say CFAST, for the sake of
25 argument.

1 Now we define the input for CFAST and
2 the uncertainties associated with it in some other
3 document. When it comes to the damage and the
4 effect or the use of the output of the CFAST, it's
5 damaged criteria. There is a distribution
6 associated with that that is generated from fire
7 testing. What is our understanding of the response
8 of let's say a cable to certain temperature exposure
9 or flux. The problem in the middle we're trying to
10 deal with is what is our understanding or
11 uncertainty, for lack fo a better word, of this
12 middle piece of the model.
13 If we happen to put the exactly correct
14 heat release rate and all inputs into it, and we got
15 the temperature that we got out of it, how much
16 uncertainty have we introduced because of the model
17 uncertainty, of the uncertainty of the CFAST itself.
18 This is what we're trying to deal with in this
19 project, the uncertainty of CFAST.
20 MR. APOSTOLAKIS: But you don't do that.
21 You're giving me colors. You're telling me zero
22 plus.
23 MR. NAJAFI: We'll get to that. Well,
24 we'll get that.
25 MR. APOSTOLAKIS: I have no idea what to

1 do with that.

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

3 that.

4 MR. APOSTOLAKIS: Warn me.

5 MR. NAJAFI: Yes, I know. Colors are

6 extremely important. I have no idea how to use

7 them. I haven't seen them anywhere else so.

8 MR. NAJAFI: We will come back to that

9 at the --

10 MR. APOSTOLAKIS: Well, the thing is

11 that you keep talking about predictive capability.

12 In previous slides, you said quantitative, if

13 possible and so on. And then I look at your final

14 result, and it's yellow plus yellow plus green,

15 yellow, and not applicable. I have a big problem

16 with that.

17 MR. NAJAFI: Yes. Well --

18 MR. APOSTOLAKIS: I have a huge problem

19 with that. I don't know what to do with colors.

20 MR. NAJAFI: I think I can say as a user

21 what to do with those color. It was our intent --

22 MR. APOSTOLAKIS: I'm waiting to hear

23 you.

24 MR. NAJAFI: Okay.

25 MR. APOSTOLAKIS: I'm anxious to hear

1 what you have --

2 MR. NAJAFI: It is true that it's a

3 challenge. Ideally, ideally, we wanted, as research

4 people, to provide a distribution, but it is my

5 understanding, and I think that this team can speak

6 for themselves, we tried to build a consensus.

7 Neither the evidence gives us enough comfort to give

8 you that level of precision. It does not. We

9 tried, and we were not able to get to that level of

10 precision. And --

11 MR. APOSTOLAKIS: Okay. We'll come back

12 to this --

13 MR. NAJAFI: -- that is a desired --

14 it's -- you may be -- you're correct that that's the

15 desired outcome, but can we accomplish that level of

16 precision at this time, it is my judgment that we

17 could not.

18 MR. APOSTOLAKIS: Amount of time? Is

19 this progressing or continuing or -- Yes, sir, who

20 are you, and tell us what you want to say.

21 MR. JOGLAR: My name is Francisco

22 Joglar. I work for SAIC. I'm part of this team.

23 MR. APOSTOLAKIS: Good.

24 MR. JOGLAR: The question you're raising

25 suggests to me that in a risk, in a Fire PRA,

1 ideally we would like to see something like my fire
2 mole is predicting this number, and I would
3 associate that number which ends up as some damage
4 to a probability of that thing being correct so that
5 we could use it. This didn't recognize that need,
6 and we have put together a method and a way of
7 organizing data that we think eventually will
8 support that goal. Okay? And I've seen methods
9 from all uncertainty that would give us that this
10 doesn't get to that point, but in those methods that
11 I've been familiar with, the way we have organized
12 the data and developed this method will support.
13 MR. APOSTOLAKIS: When will it do that?
14 MR. JOGLAR: I'm just a technical
15 person. I don't have an answer for the when, but I
16 am confident that it can be --
17 MR. APOSTOLAKIS: You're asking this
18 committee to bless this document, and I'm
19 questioning its usefulness. Are you telling me in
20 the future, it will be useful?
21 MR. JOGLAR: It is still useful now
22 because there is -- we did add a section that
23 explains how to use these results.
24 MR. APOSTOLAKIS: And I read that
25 section, and I'm not sure I like it, because not

1 only do you give me colors, you're asking me to go
2 back and make sure that the data that were used in
3 the tests and the data in my scenario are consistent
4 with each other. You're asking me to do too much.
5 You're asking me to go back and reproduce everything
6 you've done. Maybe it's too premature. I'm just
7 warning you that the color business will be a
8 central point of the discussion today. So let's go
9 on, Bijan, because I don't want to destroy your
10 presentation.
11 MR. NAJAFI: No. I know that that is a
12 challenge. That's why I raised it as a big
13 challenge.
14 MR. APOSTOLAKIS: I'm sure you're aware
15 of it. I mean you guys weren't born yesterday but -
16 -
17 MR. NAJAFI: Yes. And I think --
18 MR. APOSTOLAKIS: That's not my problem
19 too.
20 MR. NAJAFI: Yes. More than you -- I
21 shouldn't say that, but we understand.
22 MR. APOSTOLAKIS: You understand that
23 problem more than I understand it.
24 MR. NAJAFI: No, no.
25 MR. APOSTOLAKIS: That's very good,

1 Bijan.

2 MR. NAJAFI: No, no. I think it's a --

3 I understand that that's a very important thing, and

4 that's why I think.

5 MR. BONACA: Yes. And more than only

6 the simulations and what do you do with this for the

7 PRA. I must say that reading this, when I got to

8 the end of it, knowing the FIVE for example has been

9 used extensively in the plant applications, new

10 estimations, I am puzzled by this table, because I

11 could not -- I really wondered at the end of that.

12 I said, you know, how can they make projections and

13 calculations. I mean what kind of information are

14 they getting from I was just thinking of FIVE or

15 FDT. And, you know, you're left with that question

16 in your mind. I mean all we can say is n/a, n/a,

17 n/a, n/a about all these attributes or parameters.

18 And you have a couple of yellows there plus or

19 minus, so it says be cautious on how you apply it.

20 What does it mean be cautious? I mean I'm left with

21 all those questions.

22 MR. NAJAFI: No.

23 MR. APOSTOLAKIS: That's my problem,

24 too. I look at this multi-volume report, and all I

25 get out of it is that I have to be cautious.

1 MR. BONACA: I really wouldn't know how
2 to be cautious about some of this stuff.
3 MR. APOSTOLAKIS: But I think we should
4 let Bijan go on, but I think this was --
5 MR. NAJAFI: I think we will try to
6 attempt -- I will try to attempt --
7 MR. APOSTOLAKIS: Okay. Go ahead.
8 MR. NAJAFI: -- to tell you how I would
9 use it if I was the user at the end, those colors --
10 MR. APOSTOLAKIS: Okay. Maybe you'll
11 see my point.
12 MR. NAJAFI: -- and we'll see where it
13 goes. I mean I guess the bottom line is that my
14 opinion, we're not where we -- at the precision that
15 you're talking about, but I think we have results
16 that it's useful. We'll talk about that. But
17 basically the challenges that we faced, I mean in
18 here, is -- I mean some of the underlying reasons
19 for those difficulties that -- a couple of
20 fundamental things is that what is the
21 appropriateness of the model to the fire scenario.
22 I mean we have a fire scenario that we know what it
23 wants. We need to understand how close and how well
24 these fire model that we are using represent those
25 scenarios. And this is one challenge. This is hard

1 to basically -- we know in many cases, they may or
2 may not. In fact, you'll see examples. There are
3 examples that are listed in some other parts of the
4 NUREG 6850. There are fire scenarios that there is
5 no current models to deal with it, like a high
6 energy arching fault or the cable fires are some of
7 those examples.
8 The second challenge is that basically
9 to be able to tie in or understand the
10 appropriateness of the experiment or experiments
11 that we're using to the fire scenarios and obviously
12 --
13 MR. APOSTOLAKIS: Excuse me, Bijan. My
14 understanding is from reading the reports, and maybe
15 it's a wrong understanding, you use the results of
16 existing experiments, or did you actually fund
17 running experiments?
18 MR. NAJAFI: A combination of both. We
19 used an existing experiment that was done in the
20 80's, and there were a number of experiments that I
21 would -- we'll talk about -- Anthony will mention
22 some of those -- that were done at NIST that were
23 used in the last couple of years.
24 MR. APOSTOLAKIS: But this international
25 --

1 MR. NAJAFI: That's included. That's --
2 basically that's what I --
3 MR. APOSTOLAKIS: But that was done as
4 part of this study or was there a separate --
5 MR. NAJAFI: I would let NRC speak
6 whether that was done for support of this --
7 MR. DREISBACH: It was for support of
8 this project. We - It was an exchange program more
9 or less whereby we created a set of experiments that
10 NIST performed for us, specifically for a V&V
11 document. And we traded that data with the
12 International folks for the same purposes. So they
13 conducted experiments for their own verification
14 efforts and provided that data to us. And we in
15 turn provided our data to them. And that's how we
16 obtained the data that we did to use in this
17 project.
18 MR. NAJAFI: So I guess the answer is
19 yes, there are some tests that were done for this
20 particular project. But I guess the message there
21 is -- I mean there is not today and not probably for
22 a long time enough experiment to mimic all the
23 scenarios that we need to deal with. I mean --
24 MR. APOSTOLAKIS: And not enough
25 experience, actual operating experience --

1 MR. NAJAFI: And there are a few --
2 there are some, like for high energy arching faulty,
3 there may be some operating experience, some
4 evidence or certain things, but there are really not
5 that many to go by, so that's the other challenge.
6 So --
7 MR. BANERJEE: Is this very different
8 from what happens in chemical plants? There's a hug
9 database there.
10 MR. NAJAFI: The scenarios, it could be
11 different. Because the scenarios in a chemical
12 plant -- I'm by no means an expert in a chemical
13 plant -- but they are -- they should be, if they're
14 not, more concerned about toxicity and what is
15 generated in a fire as opposed to the temperature of
16 the radiation of a fire. I mean --
17 MR. APOSTOLAKIS: Well, they're
18 interested in both, because vessels fail due to
19 external fires. And there's a lot of concern about
20 vessel failure which can actually propagate and
21 cause other vessels to fail. So there's a lot of
22 concern about heat and radiation, especially on
23 external fires. Of course, a lot of data on
24 internal fires, too.
25 MR. NAJAFI: We could have used -- I

1 mean experiments -- I mean we went through and
2 defined out our scenario, because we wanted to know
3 what are the issues that it's facing to the nuclear
4 power industry. But then when we started looking
5 for experiments to use, we basically -- I believe we
6 did look first into the experiments that were done
7 uniquely for nuclear power plants, and we did not
8 cast a wide net to find out if other industries,
9 aerospace, chemical or other people -- I mean NRC
10 may have done that, but we did not, because we were
11 -- I mean at the time, we felt that a sufficient
12 test was done in Sandia, at NIST, way back. We had
13 a number of tests to go by, but our challenge is
14 that we do not have at the time even tests that can
15 I mean clearly represents the attribute of a nuclear
16 power plant fire. I mean to go even outside.
17 MR. APOSTOLAKIS: So you have to tell us
18 what's so unique about that, right..
19 MR. NAJAFI: Yes.
20 MR. APOSTOLAKIS: You're going to tell
21 us?
22 MR. NAJAFI: We're going to try. We're
23 going to try.
24 MR. APOSTOLAKIS: Right.
25 MR. NAJAFI: We're going to try what's

1 unique about that.

2 MR. APOSTOLAKIS: And when you have

3 these models, to validate them, I'm sure that your

4 experiments are not just plant specific, right.

5 MR. NAJAFI: Oh, absolutely.

6 MR. APOSTOLAKIS: They should have some

7 generic importance?

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

9 MR. APOSTOLAKIS: Then why do you

10 neglect databases in other industries which could be

11 generically important?

12 MR. NAJAFI: Because the generically,

13 then it has to apply through the industry. It's a

14 difference.

15 MR. APOSTOLAKIS: You have to show us

16 what's different generically between your nuclear

17 fires and your chemical fires, right?

18 MR. NAJAFI: I will try to explain what

19 I think is the attributes of the nuclear power plant

20 fire scenarios. We will try to explain that. And I

21 guess how is that different from a chemical

22 industry, I will only can speculate. I mean I can -

23 MR. APOSTOLAKIS: Because you know that

24 the insurance industry has been very active in this

25 area, and two of the largest losses come from either

1 fires or explosions in the process industry. And
2 because of that, this is a very, very extensively
3 researched area, and there are, you know, whole
4 companies devoted to this.
5 MR. NAJAFI: In fact, we did have
6 research for -- we did look into NEIL, Nuclear
7 Energy Insurance Limited, the insurance company that
8 basically insures nuclear power plants, but not
9 general, non nuclear insurers. But we did ask and
10 get information from the nuclear insurers. But,
11 again, I mean you have a point that why did we not
12 use non-nuclear experiments potentially out there,
13 and all I can say it was basically a limitation of
14 resources, and we chose to use experiments that we
15 had that were conducted for nuclear facilities.
16 MR. APOSTOLAKIS: Particularly, as you
17 were saying, there's a paucity of data, right?
18 MR. DREISBACH: And I think there still
19 is, because some of the experiments that you might
20 talk about outside of the nuclear industry and
21 related to other industries. Not only did we want
22 to characterize the nuclear industry type of fires,
23 we wanted to make sure these experiments captured
24 the appropriate data by which we could use to
25 compare with the models. And sometimes in those

1 types of experiments, we don't get the data capture
2 that we would need to fully evaluate the model that
3 we're dealing with here, that we wanted to deal
4 with. So there is a lot of --
5 MR. BANERJEE: So is this just the
6 fueling or you have some quantitative --
7 MR. NAJAFI: A good example of it is
8 that -- I mean we are concerned about small long
9 duration fires. I don't know if that's something
10 that a chemical is interested in. I guess the
11 bottom line is that for us, it was an effort to go
12 and look at those experiments and make a case that
13 they are valid, because any data that we use outside
14 of our industry, it is our responsibility to make a
15 case that it is valid. We're not going to
16 automatically assume that it's valid. We have to
17 make a case that it does apply to our industry. We
18 have to make a case.
19 MR. BANERJEE: Yes, but presumably these
20 models have some fundamental science in them, and if
21 they do, then experiments which are directed towards
22 clarifying these fundamentals are valid whatever the
23 industry. I mean a fire is a fire at the end of the
24 day. Whether the control room is a chemical control
25 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

1 going on and why the larger fire database from other
2 industries might or might not be applicable.
3 But I guess I would make the point that
4 what we're really talking about is whether or not we
5 can reduce the uncertainty in the validation of the
6 models by having better data. And I think on top of
7 that, we would have to add is there a payoff to
8 going and getting more data, and I don't know
9 whether there is or isn't, whether the uncertainty
10 is such that you have a gap in your usability.
11 MR. NAJAFI: Well, the thing is that
12 always it depends on the quality of the data. Until
13 you get the data and put it in there, you don't know
14 whether it's going to improve your results or not.
15 And it may.
16 MR. APOSTOLAKIS: Some of your
17 collaborators, like NIST, must have experience with
18 other industries, and some of the International
19 people, and some of your reviewers. The reviewers
20 were not exclusively nuclear people, so did any of
21 those researchers raise the issue and say something
22 about it.
23 MR. HAMINS: May I try to answer your
24 question? My name is Anthony Hamins. I am at NIST.
25 I'm the leader of the Analysis and Prediction group.

1 I'm an experimentalist. I'm the sole
2 experimentalist in this group. We did a search of
3 the fire literature in order determine well-
4 documented comprehensive compartment fire test data.
5 It had to be well-documented, because our emphasis
6 on experimental uncertainty and understanding the
7 details. In order to do a comprehensive comparison
8 of models and experiments, we needed to understand
9 the experiments that were undertaken. So we needed
10 extremely good documentation.
11 We needed something that's not typical
12 in the experimental literature, which is an analysis
13 of uncertainty. Uncertainty has recently been
14 emphasized at a number institutions and
15 international organizations, but in previous years
16 it has not been. So there is much data in the
17 literature that is, I would say, not comprehensive
18 and not well-documented. And that's why NRC has ben
19 funding studies in this experimental area for
20 validation. That's why the international community
21 got together in the ICFMP group to search out and
22 create databases for model validation.
23 We work with chemical industry. We work
24 with the Navy for example. I'm very familiar with
25 the kinds of experimentation that they're funding.

1 And we are not aware of any experimental database in
2 the literature that we could use. We selected data
3 that was the appropriate data, and I'll talk a
4 little bit more about that during my presentation.
5 MR. APOSTOLAKIS: So I take it then that
6 your answer to Professor Banerjee's question is that
7 you are aware of what is happening in the chemical
8 and other industries, but you decided that they were
9 not appropriate or they were not in a form that
10 could be used by us?
11 MR. HAMINS: That's correct.
12 MR. KHALIK: Do you have a documentation
13 of this process?
14 MR. HAMINS: Of the selection process of
15 the experiment?
16 MR. KHALIK: That's right, the exclusion
17 of data from other industries.
18 MR. HAMINS: I'm not sure that we have a
19 documented process of that literature. Now we could
20 go through the literature and document which tests
21 were not selected and the reasons for each of the
22 decisions for each of the tests. We could possibly
23 do that, but we have not done that at this point.
24 MR. BANERJEE: The fire models that you
25 have are generic models I take it, so they're not

1 specific just to the nuclear industry. I was
2 looking through your documents.
3 MR. HAMINS: Yes.
4 MR. BANERJEE: So they're validated only
5 with data from the nuclear industry or --
6 MR. HAMINS: The nuclear industry, NRC
7 has taken a lead role here in validation. In the
8 fire literature, there has been very little
9 comprehensive validation work. This is really a
10 unique comprehensive study. This is the largest
11 validation study that I'm aware of. In my 20 years
12 of fire research, I've never seen a study as
13 comprehensive on validation.
14 MR. APOSTOLAKIS: But, you know, reading
15 FIVE for example, and I was familiar with it and
16 also with other models, there are various empirical
17 or semi-empirical formulas for the height of the
18 fire, the ceiling and so on. Now when people
19 propose models like that in their general fire
20 literature, how do they convince you for example
21 that the model is valid or is useful. I mean you
22 say that this is a unique study. I understand that
23 it may be unique because of its scope and size, but
24 surely when say Professor Quintiere proposed his
25 model which you're referring to, he's provided some

1 evidence that the model gave reasonable predictions.
2 So how is that process differing from what we are
3 doing here?
4 MR. HAMINS: Jason, do you want to try -
5 MR. DREISBACH: Well, that process
6 didn't take a systematic approach sort of like
7 there's a lot of models, say Dr. Quintiere's models
8 for instance, the MOU model for temperature and hot
9 gas layer, there's a lot of other people that have
10 created similar type correlations. They've all used
11 data to provide evidence that their particular
12 correlation is reasonable.
13 MR. APOSTOLAKIS: So data means, you
14 know, it says, look, this guy did this experiment.
15 I ran my code, and I'm within 20 percent. I mean
16 that kind of data?
17 MR. DREISBACH: That's not what the
18 typical validation or confidence level is. It's
19 more of a general kind of statement as far as a
20 judgment. This provides reasonable approximation.
21 MR. APOSTOLAKIS: What's reasonable?
22 MR. DREISBACH: That's --
23 MR. APOSTOLAKIS: I mean if they use
24 data --
25 MR. DREISBACH: That's what we're trying

1 to answer here. There has been no definition of
2 what reasonable or good predication is in the
3 previous fire literature.
4 MR. APOSTOLAKIS: But there is a whole -
5 - I mean there is a general fire safety and so on.
6 I can't imagine that a guy proposes a model, and
7 then he says I think it's reasonable. I mean there
8 must be some quantitative evaluation.
9 MR. PEACOCK: I'll be happy to address
10 that. I'm Rick Peacock from NIST. I've been
11 involved in the development and the use of zone fire
12 models for the last 20 years and am particularly
13 interested in model evaluation. One of the things
14 you see, and you're correct, there is a tremendous
15 number of articles out there of people comparing
16 model x to some set of experiments. If you look at
17 those as a whole, and I have actually collected a
18 couple of slides of these, there's two
19 characteristics of those papers that it comes close
20 to 100 percent, these attributes exist in all the
21 papers. One is that all of the comparisons end up
22 being qualitative. There's quotes like "the model
23 looks good", "the model compares well", "the model
24 predicts acceptably", and the second thing is
25 they're all positive. Rarely is there a negative

1 connotation for these set of comparisons.

2 So certainly there is a broad literature

3 certainly for the models we developed here at NIST

4 of both NIST as well as others providing evaluation

5 and validation of these models for a wide range of

6 applications from small compartments to multi-story

7 hotel rooms to large atria. And that exists not

8 only just for the models but also for the sub-models

9 as well. All of that stuff is typically documented

10 in the technical reference guides for the models.

11 That's certainly the case for CFAST. That's

12 certainly the case for FDS. What we tried to do

13 here is not duplicate all that effort but focus that

14 effort on being quantitative as much as we could and

15 in focusing on scenarios that were of interest to

16 the nuclear industry. So what that says to me is we

17 don't have to use the entire universe of data,

18 rather we chose the best quality data we can and the

19 ones that best represent the scenarios that we see

20 in nuclear power plants.

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

22 sir.

23 MR. JOGLAR: Thanks.

24 MR. APOSTOLAKIS: Yes, sir.

25 MR. JOGLAR: If I may --

1 MR. APOSTOLAKIS: I guess you have to
2 repeat your name.
3 MR. JOGLAR: My name is Francisco
4 Joglar. I work for SAIC. My comment may even go
5 back to your first question is that we also had the
6 challenge that these products will be used for
7 regulatory purposes, and that sometimes ties our
8 hands in suggesting how would regulators use our
9 results. So in a way, we are kind of forced to just
10 report the validation results kind of in an
11 independent way and let regulators decide what to do
12 with that, because in some ways we are kind of --
13 our hands are tied in telling regulators how they
14 would use these results for their applications.
15 MR. APOSTOLAKIS: Can you give us an
16 example where the NRC tied your hands?
17 MR. NAJAFI: Let me clarify that. What
18 he is talking about is that the MOU basically it
19 allows us to collect data, analyze data, and present
20 the results of the data. How that it's going to be
21 used in a regulatory framework, is not the job that
22 we can do at this MOU. That's what he means.
23 MR. APOSTOLAKIS: I understand that.
24 MR. NAJAFI: But coming back to your
25 question, that might be slightly different how a

1 user will use that. That's why I said we'll come
2 back to that one later, and in fact we will hear
3 towards the end of this presentation that one of the
4 projects that Gary Vine talked about is a fire
5 modeling users guide, that something like this will
6 even expand even further into a fire modeling users
7 guide that says how a user can use these color-coded
8 results. I know that we came up with a pseudo-
9 quantitative, but I want to emphasize, I guess, this
10 is the feeling of the entire team that given where
11 we are, this is the best we were all collectively
12 were comfortable to come up with.
13 MR. APOSTOLAKIS: Well, the reason why
14 you're getting these questions from me -- I can't
15 speak for my colleagues -- is because I read these
16 reports from the user's perspective.
17 MR. NAJAFI: I understand. I
18 understand.
19 MR. APOSTOLAKIS: The whole thing --
20 every time I read a paragraph, I asked myself how
21 would that help me if I were to do a Fire PRA, how
22 would that help me if I had to implement 5048-C and
23 so on and so on. And that's why you get these
24 questions.
25 MR. NAJAFI: Yes. Those are the first

1 questions I ask myself. Those are the first
2 questions.
3 MR. APOSTOLAKIS: And we're a very
4 practical agency here. We do make decisions. I
5 mean --
6 MR. NAJAFI: And in fact, the first time
7 around, we came up with numbers and ranges, and then
8 when we realized --
9 MR. APOSTOLAKIS: The follies of your
10 ways.
11 MR. NAJAFI: No. Because everybody
12 started saying ifs and buts, and they started adding
13 ifs and buts, four pages of ifs and buts. And I
14 said, that's not useful to the user. If you said
15 use plus or minus this much with that if, and if you
16 give them two pages of if and but, that's just as
17 not useful as giving them a graded, what I call a
18 graded, range of shades. So, I mean we'll talk
19 about how --
20 MR. KHALIK: The comment was made
21 earlier sort of criticizing earlier assessments of
22 models as being qualitative in nature, and the
23 question in my mind is what's the difference between
24 that and the color code that you came up with. It
25 is still qualitative.

1 MR. NAJAFI: No. I believe it's half
2 qualitative. I believe it's halfway in between.
3 Because we assign a range. These ranges and these
4 numbers have quantitative bases in them. We very
5 clearly have quantitative numerics that is outlined
6 in the appendices that it derives these ranges.
7 MR. DREISBACH: We don't claim to reduce
8 qualitative judgment. We want to reduce some of the
9 qualitative and judgment aspects of the decisions,
10 so we add some quantitative, but we're not
11 absolutely --
12 MR. APOSTOLAKIS: I think our discussion
13 and concerns will be better addressed if you
14 actually -- I don't know whether you plan to do this
15 -- walk us through an example in detail. Here is
16 what we had. Here is the test. Here's what we did.
17 Here are the uncertainties. This is how we decided
18 it was yellow plus.
19 MR. DREISBACH: Presentations along
20 those lines.
21 MR. NAJAFI: When we get to that putting
22 the results up, I will try to go through one
23 example.
24 MR. APOSTOLAKIS: That's a very
25 important part. I mean I don't know.

1 MR. NAJAFI: No, I -- believe me, I
2 under --
3 MR. BANERJEE: The feeling that I'm
4 getting from the discussion is that let's say the
5 results of an experiment are pretty sensitive to
6 things like initial conditions and scenarios, so
7 they're sort of classically ill-posed problems,
8 which means you don't get sort of a deterministic
9 outcome because small changes in initial conditions
10 can make a big difference in the results. Is that
11 true? In a sense, it's inherently uncertain?
12 MR. DREISBACH: And that's part of what
13 we're trying to get to.
14 PARTICIPANT: But come on guys, define
15 the catch rise with yellow pluses. So it's
16 turbulence. Yes.
17 MR. APOSTOLAKIS: This industry has
18 dealt with severe accidents, and I can't imagine
19 that your problem is more difficult than predicting
20 what happens in a containment when the corium starts
21 moving around. And yet --
22 MR. BANERJEE: That's science fiction.
23 Right.
24 MR. APOSTOLAKIS: But yet 1150 came up
25 with some estimates, some uncertainty estimate, they

1 had experts, they had reviews, and their estimate
2 were consistent with the PRA. So it's not like
3 we're dealing with an entirely -- and they were-- in
4 fact that's why I'm saying this, because I remember
5 in the review process, we had a gentleman who was
6 not a nuclear person, he was a fluid mechanician,
7 and he said exactly the same the thing. When I do
8 experiments, I know that some things -- if I change
9 a few things in the inputs, I may have a lot of
10 changes in the output, and you guys are telling me
11 you know what's going on in this big volume and all
12 that. So I mean we have handled it in the past.
13 Okay?
14 And then in the thermohydraulics area,
15 these CSAU method that systematically walks you
16 through a process that ends up with a statement of
17 uncertainty, correct Hossein? So did you take
18 advantage of these things? I mean did you look at
19 CSAU and see whether what you're doing is
20 consistent? I mean after all, it's an NRC method.
21 Don't ask me more. I will rely on my colleagues
22 here to --
23 MR. NOURBAKHSH: The scaling methodology
24 for severe accidents. Actually, it's a NUREG.
25 Discusses the process on first of all for each

1 scenario, you define your figure of merits, what are
2 the important at attributes for that scenario, and
3 then that provides you an input to quantifying the
4 scaling distortion, these elements of scaling, and
5 the impact of whether in your experiment there are
6 distortions, and even how you incorporate some of
7 these uncertainties and the separate effect
8 experiments, and then you take --
9 MR. NAJAFI: I guess I will express the
10 response in two pieces. First, I don't think the
11 problem we have is any simpler than that. It's just
12 as hard. But you're correct. I mean we started
13 with this project with the objective of validation
14 and verification of these codes and how do we
15 characterize this into a probabilistic framework.
16 It was not defined at the early on as the objective
17 of this project.
18 MR. APOSTOLAKIS: Did you look at CSAU
19 at all?
20 MR. NAJAFI: We looked at a methodology
21 that was developed for the fire modeling uncertainty
22 by the NRC, Nathan Su, and I mean we looked at --
23 Francisco can talk about that a little bit maybe --
24 but we did look at alternatives. We looked at
25 options. I don't know specifically about SCAU but

1 methods out there that have been used to deal with
2 the uncertainty and physical phenomena. And that is
3 not or was not part of the scope of this work.
4 MR. APOSTOLAKIS: Because you followed
5 the ASTM standard.
6 MR. NAJAFI: Yes.
7 MR. DREISBACH: That's what we followed.
8 That's the methodology we followed --
9 MR. APOSTOLAKIS: But I mean --
10 MR. DREISBACH: -- because it's written
11 for evaluating the predictive capabilities of
12 models, fire models specifically. So we determined
13 that was a way we needed to approach the product,
14 because there is a standard out there.
15 MR. APOSTOLAKIS: I would expect though
16 that when you selected these, you would also look at
17 other methods that have been used by our agency and
18 see whether, you know, some sort of hybrid would
19 have been better or -- anyway, I think we are
20 spending too much time on this and let's move on.
21 MR. NAJAFI: The project team,
22 basically, to cover, we see through the next slide,
23 there are several expertise or critical scale area
24 that we considered very crucial to this. One is the
25 nuclear power plant fire scenarios. This is very

1 important understanding what these critical issues
2 are. We'll talk about that. I know you guys need
3 to know. EPRI and NRC, through basically fire
4 modeling guide, the training, and the SDP process,
5 we've had experience with what these scenarios are.
6 And for us, we had fire science and model
7 development in NIST, EDF, EPRI and NRC to ensure
8 that we understand well the strength and weaknesses
9 of these models and where and how these map or match
10 into the fire scenarios and attributes that we're
11 interested in, and we had experimentalists to ensure
12 that we understand the appropriateness of these
13 experiments towards the scenarios at NIST that they
14 brought to this team. We had an independent review
15 of this project by Professor Quintiere and Dr. Beyer
16 and Phil DiNenno primarily for the fact that these
17 people were key, some of the individuals involved in
18 those correlations went into our hand calculations.
19 MR. APOSTOLAKIS: Now are you coming
20 back to the scenario business later or?
21 MR. DREISBACH: In the next few slides.
22 MR. NAJAFI: In the next few slides.
23 MR. APOSTOLAKIS: Said?
24 MR. KHALIK: Well, I was going to ask
25 about that. Presumably you selected these scenarios

1 to capture what you have referred to as the unique
2 aspects of fires in nuclear facilities?
3 MR. NAJAFI: Yes.
4 MR. KHALIK: And you will go through
5 that process of how these scenarios particularly
6 capture those unique aspects?
7 MR. NAJAFI: Yes, sir.
8 MR. KHALIK: Okay.
9 MR. NAJAFI: The next couple of slides
10 is basically where we talk about the public
11 comments. We have received extensive comments over
12 a period of 60 days, and we've - the document you
13 have reflects that --
14 MR. APOSTOLAKIS: Yes. We've read that.
15 You responded to each one of them. Let's move on.
16 MR. DREISBACH: Okay.
17 MR. APOSTOLAKIS: Well, I'm trying to
18 get -- you know, there is a lot of discussion and
19 things. I don't want to --
20 MR. NAJAFI: Okay. And then the next
21 one is basically the presentations to come.
22 MR. DREISBACH: So now I'm going to sort
23 of try and go through our technical approach. We've
24 already obviously talked about quite a bit of what
25 we went through, but I just wanted to put up

1 definitions of verification and validation. When we
2 were here in front of the ACRS last year, this was a
3 question we were asked, "What is your definition of
4 verification and validation", so I wanted to make
5 sure we revisited this to get everybody on the same
6 page here.
7 So our approach to verification is
8 making sure or understanding whether the model was
9 built correctly, basically the mathematics and
10 numerics of the code. And then validation was was
11 the correct model built, basically are the physics
12 of the model representative of what we're trying to
13 answer or what the solution is.
14 And then one of the key things that the
15 NRC wanted to make sure this process was about was
16 the transparency. So after this process is over,
17 all of the data that we used, all the model inputs
18 that we used, all the model runs that we provided,
19 the inputs to the models, they will all be in the
20 public domain so that anybody who wanted to rain
21 event visit or try and recreate this process
22 themselves, they will be able to do that. And since
23 the experimental data will be available, anybody who
24 wants to use a different model and go through the
25 same process or even a different process, all that

1 stuff will be available. We'll make that available
2 in the public domain.
3 So that leads us to what do we need to
4 do to do verification and validation. And so we
5 asked ourselves these questions to get at a process
6 that we could use. Obviously, the first one up in
7 question so far this morning, "What scenarios are of
8 concern, what are the important measurement and
9 parameters of those scenarios that we're concerned
10 about." Then we wanted -- to provide validation, we
11 have to have some sort of experimental database.
12 And so what experiments have been performed that
13 will address these kinds of concerns. And then we
14 needed to see what models are out there that we can
15 use to do these kind of things. And how do we
16 evaluate those models. That's what we're going to
17 step through here. And sort of the user aspects,
18 "How do we know if a model is valid for a specific
19 circumstance." That was the basis of our approach
20 to going through this.
21 And as we've mentioned already, this
22 ASTME 1355 provides us with an approach to step
23 through those questions. It's a standard approach.
24 It's an international standard. Something that's
25 important to us -- we didn't want to reinvent a

1 wheel. We could potentially have used other
2 methods. This is the one we chose because it
3 specifically catered to evaluating the predictive
4 capabilities of fire models.
5 It's a process obviously, so what we've
6 already established is the hard part is what is the
7 degree of accuracy required. What does the
8 regulator need to be confident in an analysis that
9 uses one of these models. So that was part of what
10 we had to establish in this process to be able to
11 use what our results were in a wider scope than just
12 the experiment to be considered. So this standard
13 suggests an approach of a specific evaluation
14 technique, many evaluation techniques actually, but
15 it doesn't require one over another. So there is
16 some flexibility as far as some of the things that
17 we used that is in the standard.
18 Now I'm going to leave it up to Bijan
19 again to talk about more specifically the scenarios
20 and the measures and parameters.
21 MR. NAJAFI: Okay. This is the part of
22 the presentation that I guess I'll hope will answer
23 your question about what are the nuclear power plant
24 scenarios that we talk about. I guess one of the
25 first steps to the validation is for us to determine

1 any, and this is where the need comes in --these
2 nuclear power plant fire scenarios were first
3 developed as a library by EPRI in 2000, and
4 published in a document in 2001. The process for
5 selection, and this was basically the intent at the
6 time, was to generate a document as a guide, that if
7 somebody wants to do fire modeling in a nuclear
8 power plant, basically how do they go about to do
9 that. And that process had basically almost like a
10 guide or manual that says you do this first, and do
11 this, do this, do this, do this, do this.
12 In order to develop that, you have to
13 understand what are the questions that people may
14 ask, what do they want to use it for, and that the
15 first need was to develop a library of fire
16 scenarios that they will likely be analyzing. So we
17 did this, we went first, looked at the result of the
18 IPEEE that was done during the late 80's and early
19 90's. That was probably the most - for the nuclear,
20 the most widely used risk and fire modeling on an
21 industry-wide basis, meaning the people went around
22 and analyzed their plant and the fire scenarios in
23 their plant.
24 So we created, looked, reviewed almost a
25 number of about 70 IPEEEs to get input from their

1 fire scenarios. Then we surveyed the industry. We
2 sent a survey to the industry and said, "Tell me
3 what have you used fire modeling for outside of
4 IPEEE for some exemption, for whatever". So we got
5 some answers from them. Then we surveyed the NRC
6 NRR, and we sent some questions to them and said how
7 many submittals have you received from the industry
8 or somebody based on fire modeling, and what was the
9 example of it. So we took all of that data and put
10 it into information and created a set of what we
11 call library of nuclear power plant fire scenarios.
12 Now, how did we define these? We
13 defined these on basically --
14 MR. APOSTOLAKIS: Before you move on, I
15 assume you looked at the actual Fire PRAs that have
16 been done for some plants, not just the IPEEEs?
17 MR. NAJAFI: Yes. We looked at older
18 ones.
19 MR. APOSTOLAKIS: There is a statement
20 in the first volume that intrigues me and is related
21 to a scenario. I can read it to you. "The scope of
22 this V&V study is limited to the capabilities of the
23 selected fire models. There are potential fire
24 scenarios in NPP fire modeling applications that do
25 not fall within the capabilities of these models

1 and, therefore, are not covered by this V&V study,"
2 and I don't know what these models, what these
3 scenarios are. You don't tell me.
4 MR. DREISBACH: I can --
5 MR. APOSTOLAKIS: Do you tell me
6 somewhere else?
7 MR. DREISBACH: Yes. Yes. Yes.
8 MR. APOSTOLAKIS: So there are some
9 scenarios for which none of these models is helpful?
10 MR. DREISBACH: Yes.
11 MR. APOSTOLAKIS: And where can I find
12 those scenarios?
13 MR. DREISBACH: 6850, EPRI 1011989.
14 Those I'll give you an example. One example high
15 energy arching fault -- is that how the high energy
16 arcing fault in a 66 KV switchgear generates and
17 propagates the fire. We currently cannot model
18 that. Correct me if I'm wrong with any of these
19 models.
20 MR. APOSTOLAKIS: Would it have hurt to
21 --
22 MR. NAJAFI: Name -- make a list here?
23 MR. APOSTOLAKIS: Yes, to help --
24 MR. NAJAFI: Okay. No. It would not
25 hurt.

1 MR. APOSTOLAKIS: Since it's so easy for
2 you to answer it, can you send an email to Hossein
3 later, at least guide us where we can go and find
4 those?
5 MR. NAJAFI: Yes.
6 MR. APOSTOLAKIS: I'm not asking you to
7 do a lot of work, just, you know, off the top of
8 your head. Obviously, you know.
9 MR. NAJAFI: Yes. There's a list of
10 half a dozen to a dozen.
11 MR. APOSTOLAKIS: Okay. So you'll
12 provide these scenarios to us?
13 MR. NAJAFI: Yes.
14 MR. KHALIK: Also, presumably there is a
15 range of non-dimensional parameters or attributes.
16 You classify different experiments with the ranges
17 of these parameters which they cover. And the
18 question is, do you have the ranges of these
19 attributes in which nuclear power plant fires are
20 expected to fall?
21 MR. NAJAFI: In some cases, yes, we do.
22 In fact we generated that information as an input to
23 those people who conducted the validation. I'll
24 give you an example. When we defined a fire scenario
25 and we said for example for a control room, there

1 are fire scenarios in the control room, and the
2 attributes in a control room that we're interested
3 is these: First, fire propagation from one panel to
4 the next we know you can't calculate. That's one of
5 a half a dozen I told you.
6 The other one is the smoke generation
7 and migration and the timing of it we're interested.
8 Yes, these models can deal with that. And as part
9 of that definition, we said, by the way, the size of
10 the control room in this industry vary from small to
11 medium to large if it matters to your V&V. Some of
12 those ranges of parameters, I make a distinction,
13 because we talk about some other similar sounding
14 terms, but ranges of parameters we collected. Some
15 were appropriate and when used in the V&V, some
16 didn't matter. Some didn't matter.
17 For example, the size of a room in some
18 cases may not have mattered in the accuracy or
19 predictive capability of the code. It obviously
20 mattered in the answer but not the predictive
21 capability of the code.
22 But we did define those ranges. We did
23 --
24 MR. KHALIK: But I guess I'm still lost
25 in a sense that I'm trying to define the physical

1 attributes and the parameter ranges that I would say
2 this is the range of parameters in which nuclear
3 power plant fire would fall, these are the ranges of
4 geometries that I'm interested in, these are the
5 ranges of boundary conditions that I would be
6 interested in. And I need to start from something
7 like that to be able to make the connection to these
8 are the scenarios that we looked at, and these are
9 the experiments that we think match the physical
10 geometry, boundary conditions and the parameter
11 ranges that we're interested in, and I can't find it
12 in the report.
13 MR. NAJAFI: In the slides. Oh, in the
14 report?
15 MR. KHALIK: Correct.
16 MR. NAJAFI: Okay.
17 MR. DREISBACH: You're looking for
18 what's actually out there, the ranges of compartment
19 sizes that are --
20 MR. KHALIK: I'm looking for the logic
21 of the process.
22 MR. DREISBACH: Okay.
23 MR. KHALIK: I mean you may have
24 followed a rigid validation and verification process
25 spelled out in some standard, but there have got to

1 be some underlying logic. This is the problem I'm
2 interested in. These are the ranges of geometries
3 that I'm interested in. These are the ranges of
4 boundary conditions that I'm interested in. These
5 are the ranges of parameters that I'm interested in.
6 And these are the experiments, and the experiments
7 actually match the geometries, match the boundary
8 conditions, match the parameter ranges. I can't
9 find that connection.
10 MR. NAJAFI: I can only say that that
11 was -- I mean what you're saying makes logical sense
12 to me, and that was the intent of our process. If
13 it does not come across, we have to go back. That
14 was the exact objective of developing these
15 scenarios but --
16 MR. DREISBACH: We provided a
17 methodology for a user to determine the range of
18 their parameters relative to the range of the
19 parameters that we considered. That's the step that
20 we took.
21 MR. APOSTOLAKIS: Where is that, because
22 I have a similar related --
23 MR. DREISBACH: That is where we
24 describe the non-dimensional parameters. We
25 characterize that process as something that the user

1 should go through to evaluate his or her particular
2 fire scenario in order to determine the
3 applicability of our report to their scenario.
4 MR. APOSTOLAKIS: But the way I
5 understood -- maybe I didn't read that part, but the
6 statements that I read, I got the impression that
7 you wanted the user to go back and look at the
8 experiments that you guys have used and make sure
9 that his or her parameter ranges are consistent with
10 those, which I thought was a big job.
11 MR. JOGLAR: This is Francisco Joglar
12 again. And I think that's not our intent. We were
13 operating under the challenge that there are some
14 nuclear power plant fire scenarios, there are
15 experiments, and they are models, and none of them
16 fit perfectly within each other. They are
17 experiments that will never match identical nuclear
18 power plant fire scenarios, not all of them. And
19 there are models with limitations that will not be
20 able to calculate every single aspect of the
21 experiments or the fire scenarios. So that's the
22 challenge we operate. Therefore, all we could -- I
23 guess our approach was let's take these experiments
24 and characterize it with these non-dimensional
25 parameters so that people, when they're applying it

1 in their plants, they will be able to calculate that
2 number for themselves and see if it fits within the
3 experiments we have. So they don't have to read all
4 these experiments. They have to go to their plant
5 and see if the geometry, their parameters will fit
6 within the parameter for which we are providing
7 validation which is limited by the experiment. And
8 then in that way, they will be able to use the --
9 MR. APOSTOLAKIS: Are you going to talk
10 about it today?
11 MR. NAJAFI: Yes. That's why we --
12 MR. BANERJEE: So these non-dimensional
13 parameters -- sorry -- are known?
14 MR. NAJAFI: Yes. That's the approach
15 we took. They's why we talk about summary. We say
16 now that we found these charts -- that's when I told
17 you at the end we say we hope how -- a user comes in
18 with a scenario, and he knows the characteristics of
19 his scenario, the size of the room, the size of the
20 fire and everything, now we gave him this non-
21 dimensional some set of rules that says check it
22 against thee rules. This is the first frontal. If
23 you pass through this first hoop, then we validation
24 for you.
25 MR. BANERJEE: This is a very important

1 point, so I hope you go over in some detail how you
2 arrived at these non-dimensional --
3 MR. NAJAFI: Those non-dimensional
4 parameters --
5 MR. BANERJEE: -- and what the science
6 base for them --
7 MR. NAJAFI: Yes. I will leave it to
8 the statisticians and theoreticians that you don't -
9 MR. BANERJEE: We would really like to
10 know the science base behind that.
11 MR. NAJAFI: Yes. Very quickly, these
12 non dimensional parameters have been developed for
13 fire applications, so this is not something we
14 developed. They are out of the literature for fire
15 applications.
16 MR. BANERJEE: But did you validate that
17 these non-dimensional parameters actually apply or
18 that they're not simply things in the literature? I
19 mean there are lots of correlations and things in
20 the literature which may or may not apply. It
21 depends on ranges of parameters and all sorts of
22 things. I can name lots of them in fluid mechanics
23 and heat transfer where -- you know, there are
24 things in the literature, but it doesn't mean that
25 they actually work.

1 MR. NAJAFI: We'll talk about --

2 MR. BANERJEE: Oh, you're going to talk

3 about that. We would like to have a fairly clear

4 picture.

5 MR. NAJAFI: This is actually something

6 we developed internally. We had --

7 MR. BANERJEE: It's very important I

8 think.

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

10 it.

11 MR. APOSTOLAKIS: I suggest that you

12 guys -- I mean you are experienced presenters -- you

13 skip a lot of the process stuff --

14 MR. DREISBACH: Okay.

15 MR. BANERJEE: Yes.

16 MR. APOSTOLAKIS: -- and go to the to

17 the technical technical stuff as soon as you can,

18 because obviously that's the interest of the

19 subcommittee.

20 MR. NAJAFI: So then I'll leave it up to

21 you guys to see if it's clear about how do we derive

22 the fire scenarios and if you want to know anything

23 about the fire scenarios. Because the next two

24 slides that you see is basically is going to give

25 you a summary that we came up with as many as maybe

1 a dozen or 16 fire scenarios for a nuclear power
2 plant. I'll give you one or two examples of them.
3 And that defines first the scenario, and then what I
4 call attributes of the scenario, meaning what
5 parameters in that scenario are critical and
6 objective.
7 One example is a control room fire
8 scenario. What we're interested in is a fire that
9 can propagate first inside from cabinet to cabinet.
10 And second, the attributes we're interested in is
11 the amount migration and the timing of the smoke
12 that it can generate.
13 Another example is a fire inside of the
14 cable room or a cable tunnel. That fire may start
15 inside of a cable as a self-ignited cable fire or
16 may be triggered by a secondary fire. The mechanism
17 there more of a generated condition is more of a
18 flame spread, fire propagating through one cable
19 tray along its horizontal rate or through cable tray
20 stacks. That's the second scenario.
21 Another example is a large scenario in a
22 turbine building that may involve large oil fires
23 that may generate hot gases and smoke propagating
24 through grated flooring through multiple layers.
25 And the issue there is that how the smoke and hot

1 gases move from room to room. So through this
2 process, we generated switchgear rooms. These are
3 the scenarios, these are the issues, these are what
4 we're interested in.
5 In small enclosures, when you have a
6 source and a target, all we're interested in is
7 plume temperature, because in many locations in a
8 nuclear power plant source and target happen to be
9 in very close proximity. So all you have to know is
10 a plume temperature correlation, and you're done.
11 And so we defined all of these, and we
12 made a list of a dozen or 16 scenarios with as many
13 as 12 attributes that says pressure, temperature,
14 smoke density and things that we're interested in
15 with different scenarios. That's how these were
16 derived, and this basically forms for us the need,
17 go validate these. That's why we didn't calculate,
18 for example, egress time. We did calculate plume
19 temperature.
20 MR. BANERJEE: Do you have a slide with
21 the scenarios and the parameters of interest?
22 MR. DREISBACH: That's what these --
23 MR. NAJAFI: These are basically some
24 summarized version of it. We don't have one slide
25 that makes a list of all the 16. They are basically

1 in Sections 2.3 and 2.4, I believe, of the Volume I.
2 MR. JOGLAR: This is Francisco again.
3 But these slides -- these bullets are those: room
4 temperature, flame height, plume and ceiling deck
5 temperature. And as we move through the slide, you
6 would see oxygen and smoke concentration, room
7 pressure. Those are the ones that we are providing
8 validation, those parameters.
9 MR. APOSTOLAKIS: So you said in a
10 control room fire, I'm interested in knowing the
11 oxygen and smoke concentration?
12 MR. NAJAFI: Yes.
13 MR. APOSTOLAKIS: And then you ask
14 yourselves which models attempt or claim to predict
15 this?
16 MR. NAJAFI: What is the capability of
17 each model in predicting that. We don't say --
18 MR. APOSTOLAKIS: Not all of them.
19 MR. NAJAFI: We're not trying to say
20 which one is better, which one is worse, we're
21 saying that --
22 MR. APOSTOLAKIS: Some of them may not
23 even do it at all?
24 MR. NAJAFI: Exactly. That's why the NA
25 is in the boxes.

1 MR. BANERJEE: But you're also
2 interested in the propagation of the fire from panel
3 to panel there?
4 MR. NAJAFI: Where these -- remember
5 what George asked, -- where these models are
6 applicable, because the panel to panel is one of the
7 half dozen or dozen that I told --
8 MR. BANERJEE: That you cannot
9 calculate?
10 MR. NAJAFI: You cannot do that.
11 Another example is the problem in a control room
12 inside of the control board, the horseshoe, how far
13 and how fast the fire propagates, that's the a giant
14 metal box with all kinds of cables running around.
15 And how and fast and how far the fire propagates, we
16 don't do these with these computational fire models.
17 That's outside their capability.
18 Again, go to the other document. We provide
19 some empirical model to deal with that, for those
20 that we could. Yes?
21 MR. BANERJEE: But though in these
22 scenarios, there are some aspects which are handled
23 by your computational models and some you give some
24 empirical guidance?
25 MR. NAJAFI: That is correct, but here

1 in the list, you only see the computational one. He
2 is correct that we need to get the empirical one
3 embedded somewhere that says --
4 MR. BANERJEE: Right.
5 MR. NAJAFI: -- these are the ones that
6 are nuclear fire scenarios that we didn't address
7 here, it's addressed in some other document, go look
8 there.
9 MR. JOGLAR: And empirical models are,
10 we think, the Fire PRA risk framework, so that's why
11 they are in that other document.
12 MR. DREISBACH: Okay. So moving on.
13 I'm going to skip through these next two that
14 describe the experiments a little bit, because we
15 have another presentation to talk about that. And
16 we've talked a little bit about what they are and
17 where they came from.
18 MR. APOSTOLAKIS: Good.
19 MR. DREISBACH: So I'll just put this
20 slide up to show you the specifics of the models
21 that we selected.
22 MR. APOSTOLAKIS: I think 16 is
23 interesting. I mean you -- yes.
24 MR. DREISBACH: Okay. So here's - I put
25 schematics of the experiments that we considered and

1 how they relate to our overall scenarios. This
2 slide is -- these individual experiments and these
3 diagrams are going to be coming up later when we
4 talk more about the --
5 MR. APOSTOLAKIS: Just tell us about the
6 scale here.
7 MR. DREISBACH: Okay. So the turbine
8 hall, the one on the upper right, that height of
9 about 22 meters or 20 meters; the FN/SNL data,
10 that's about 6 meters, 5-1/2 to 6 meters; the pump
11 room is about 5-1/2 meters; the ICFMP 3, the one on
12 the lower left, I think that's 3-1/2 or 4 meters;
13 and the NBS multi-compartment, that's 2-1/2 meters.
14 It's basically the normal room height kind of thing.
15 MR. BANERJEE: And these experiments
16 were done in full scale or?
17 MR. DREISBACH: Yes.
18 MR. BANERJEE: With devices of mocking
19 up these dimensions?
20 MR. DREISBACH: Yes. Yes. And the fire
21 sizes ranged from, I think, on the order of 100
22 kilowatts all the way up to 4 megawatts, something
23 like that, depending on the size and the specific
24 experiment that we were looking at. But the details
25 of these experiments will be talked about by Anthony

1 in the next presentation.

2 MR. NAJAFI: And this is the link that

3 you were talking about, our scenarios and the

4 experiment. There's the kind of link you -- I guess

5 someone --

6 MR. DREISBACH: Very generally

7 obviously, because we don't have very specific

8 representation necessarily. It's not like we ran

9 tests in a turbine hall or anything like that but --

10 MR. BONACA: Although these geometries

11 are pretty representative actually of all power

12 plants.

13 MR. DREISBACH: Right.

14 MR. BONACA: Especially the switchgear

15 room. I mean this is typical.

16 MR. DREISBACH: Right. That's what we

17 were trying to do when we found the test series that

18 we evaluated. So here's the models that we selected

19 specifically. We have NUREG-1805 which has been

20 presented to the ACRS in the past, the fire dynamic

21 schools, the five model, and those are what we call

22 hand calculations of engineering calculation models,

23 libraries of models. CFAST and MAGIC are two-zone

24 type models and fire dynamic simulator. That's a

25 CFD model that used LES. And down on the bottom we

1 show sort of the varying complexities. A you go
2 down the list, you increase the complexity of the
3 model. Now --
4 MR. APOSTOLAKIS: Since we have the NIST
5 gentleman here, when you developed say the FDS or
6 CFAST, did you have any particular industries in
7 mind, any particular applications, or were they just
8 codes that addressed generic issues that most people
9 would face?
10 MR. McGRATTAN: Yes, general purpose
11 fires in a wide range --
12 MR. APOSTOLAKIS: Please identify
13 yourself.
14 MR. McGRATTAN: I'm sorry. My name is
15 Kevin McGrattan, and I'm the developer of FDS. And
16 FDS was developed for a wide range of, it started
17 with, industrial scale fire scenarios but has soon
18 moved to residential scale fires.
19 MR. KHALIK: And as a part of that
20 development, was there any validation work? In
21 other words, after you developed this code, have you
22 compared the code predictions against data or other
23 models?
24 MR. McGRATTAN: Oh, absolutely. All
25 along the way these models have been compared with

1 data. In fact, some of the experiments that are
2 discussed today were used previously in validation
3 efforts. The trouble we had was when the NRC asked
4 us about the validation work, we said, okay, here's
5 a paper we wrote five years ago showing FDS compared
6 with say these compartment experiments done 20 years
7 ago. So is that the current version of the model?
8 We said, no.
9 So what we're doing now, and this is why
10 we're emphasizing comprehensive, is we have to go
11 back, look at all the validation work that we've
12 done in the past, use current versions of the model,
13 document it more adequately, follow the procedures
14 in ASTM 1355. In the past, I hate to say it, we
15 were a bit informal and casual the way we did our
16 validation work. We developed some new routine. We
17 got some test data. We compared it. We published a
18 paper. In the end, we had a long list of
19 publications, but we had no comprehensive document,
20 like the one we're talking about today, to show
21 someone here's how the model works today, not how it
22 worked ten years ago. Here's how it actually works
23 today.
24 MR. KHALIK: But the implication is that
25 this model is an evolution, you know, that you did

1 this 20 years ago, but the model as it is now, is
2 significantly different than what it was then. Now
3 evolution will continue, so what do you expect to
4 happen five years from now?
5 MR. McGRATTAN: FDS, the field model,
6 the CFD model is evolving. We continue to do
7 research in fire, and we continue and improve FDS.
8 CFAST, the zone model, is what you would call in a
9 maintenance stage. Most of the development work is
10 completed except for special purpose functions that
11 will be added from time to time depending on the
12 application. But CFAST is generally in a maintenance
13 mode now but FDS is continuing to evolve.
14 MR. JOGLAR: This is Francisco. To
15 address your question maybe in a more programmatic
16 manner, that's why our effort here is to come up
17 with a validation and verification method that can
18 be reproduced later if things change. So we have
19 specific steps and specific ways to do it so that a
20 new version comes or a new model comes, then it can
21 be reproduced.
22 MR. KHALIK: But from a user's
23 perspective, based on the outcome of this process,
24 and the recommendations, albeit in color code, would
25 that be tied to specific version of the code as of a

1 specific date?

2 MR. McGRATTAN: Yes. Presently, it says

3 clearly in these documents which version of the code

4 was used. And if it were to be used in the future,

5 we would ask that those people use the present

6 version of the code unless we demonstrate that some

7 future version, some improved version of the code

8 satisfies all the requirements that we've put for

9 this particular application.

10 So in other words, if I come out with a

11 new version of FDS two years from now, I'm going to

12 rerun every single case that I've rerun here,

13 produce essentially the same document that you have

14 before you before we release that new version. So

15 this is the basis or the starting point of a

16 process, a more formal process that we're going to

17 use to maintain our models.

18 Like I said before, in the past, because

19 we were more in a research framework, we were very

20 casual about how we did maintenance. We're now

21 formalizing the process, and this is the first step.

22 MR. NAJAFI: And I should also add that

23 -- I mean other than FDS, the other codes,

24 particularly the hand calculations have been around

25 in the SFE handbooks for years, and those are pretty

1 much stable. And you heard about CFAST. And I
2 believe MAGIC is in a similar situation. So for a
3 majority of these -- I mean these are relatively
4 stable tools. I mean FDS may be unique in that
5 sense, but the rest of them are not.
6 MR. PEACOCK: Rick Peacock at NIST.
7 Yes, and I should also mention that some of these
8 experiments we have indeed have comparisons with
9 versions of CFAST, in my case, for the last 15
10 years. And one of the heartening things is that the
11 answers don't change that much, that it is very
12 small changes in the models that we're seeing as
13 they evolve because they're mature products. So
14 even if I do end up five years from now rerunning
15 this, I don't expect the answers to be significantly
16 from what we found today.
17 MR. BANERJEE: Let me ask you a
18 question. You've got a hierarchy of models here of
19 increasing complexity, as you said, as you go down.
20 At some point, you will, I suppose, define
21 predictive capability. And when you do that, it
22 would mean, I suppose, that the predictive
23 capability is increasing as you go down. Is that --
24 MR. DREISBACH: Well, that comes out as
25 our results more or less. We sort of evaluate the

1 models, and as you increase complexity, the question
2 is, the hypothesis is --
3 MR. BANERJEE: But does it?
4 MR. DREISBACH: -- do the predictive
5 capabilities improve and we --
6 MR. BANERJEE: What have you found?
7 MR. DREISBACH: We found that is indeed
8 the case, and it's due to a variety of reasons and
9 the degree between the levels of complexity is also
10 different when you go from one to the next. For
11 instance, when you go from hand calculations to zone
12 models, your capabilities increase, I won't say
13 significantly, but there is improvement, and it's
14 marked. And that's due to reducing assumptions and
15 limitations of the hand calculations when you go to
16 the zone models. but when you go from the zone
17 models to the FDS, you see some improvement of the
18 capabilities but not as significant a change as from
19 the hand calculations to the zone models.
20 MR. BANERJEE: In fact, I mean it seems
21 to me that your two-zone models, at least from the
22 results you're presenting, are as good as FDS. I
23 mean it's in different ways but --
24 MR. DREISBACH: One of the things that
25 we say in addition to that particular point is

1 sometimes it's going to depend on what you're
2 actually comparing against.
3 MR. BANERJEE: That's the -.
4 MR. DREISBACH: And the scenarios that
5 we've used are very much appropriate for the zone
6 model type of calculation because you get a fire
7 that produces a very, we see, distinct two-zone kind
8 of condition in a compartment, but there are also
9 other considerations that a user has to take into
10 account as far as his specific scenario, and we do
11 make that point in the conclusions part about the
12 complexity of your particular scenario and how that
13 should enter into your decision making as far as
14 what model you use.
15 MR. BONACA: It seems to me also one
16 thing that seems to me when I look at the table at
17 the end of the results, the number of parameters
18 that you can estimate or calculate is also the
19 parameter of importance it seems to me. What I mean
20 is that I look at MAGIC and practically on every
21 parameter that you have listed, you can produce a
22 result.
23 MR. DREISBACH: Right.
24 MR. BONACA: And most of them -- well,
25 many of them are green, and some of them are yellow.

1 MR. DREISBACH: Yes.

2 MR. BONACA: You know, so when I look at

3 that versus say the T, that doesn't give me anything

4 practically except the three or four parameters.

5 MR. DREISBACH: There are, and we try to

6 make this point in the conclusions, each specific

7 type of model has its application, and it depends on

8 the specific scenario and the information that you

9 want to provide.

10 MR. BONACA: Yes, but with the

11 spreadsheets, I don't get that many parameters. I

12 get two or three. I mean that's all I get.

13 MR. JOGLAR: This is Francisco. I am a

14 fire model user. I use it for plant applications.

15 And it's true what you're seeing in that table, the

16 capabilities of predicting some of the things are

17 not there. However, the importance of these

18 spreadsheets is huge, because some of these are very

19 important: plume, hot gas layer, flame height. And

20 when you go and do Fire PRAs, there are numerous

21 calculations that you have to do for every room.

22 And these things are very, very helpful. So I don't

23 want that the amount of capabilities that are listed

24 there demean the importance of these tools for

25 nuclear applications.

1 MR. BONACA: No. I don't dismiss that.
2 But it seems to me that with the spreadsheets, from
3 reading the material, that so much more is left to
4 the judgment of a fire expert than with the other
5 method that seem to calculate some parameters that I
6 can depend on.
7 MR. JOGLAR: Yes. And it's part of our,
8 I guess, the profession to determine when you have
9 to go to the other to calculate things that you need
10 for a specific fire scenario. So when you go in
11 applications, you must determine if you need to go
12 to a zone model or a field model to be able to get
13 the answer on the inside unit.
14 MR. DREISBACH: We can talk about some
15 of these things later one. I've just got a couple
16 more slides.
17 MR. APOSTOLAKIS: Yes. You're getting
18 now to the validation method.
19 MR. DREISBACH: Right.
20 MR. APOSTOLAKIS: So let's take a break
21 at this point. Okay?
22 MR. DREISBACH: That's fine.
23 MR. APOSTOLAKIS: So we'll be back --
24 let's see, when -- 10:25.
25 (Whereupon, the forgoing matter went off

1 the record at 10:10 a.m. and went back on the record
2 at 10:29 a.m.)
3 MR. APOSTOLAKIS: Okay. We're back in
4 session. Please continue.
5 MR. BONACA: Just for the record, one
6 observation that I made prior to the break, I asked
7 questions regarding the two approaches which are
8 spreadsheets approaches, and then I made a comment
9 that you don't get much from those, you have only a
10 few parameters coming out. And the answer came that
11 said, but those parameters are one of the most
12 important. You know?
13 And my suggestion is that for the sake of
14 the report, I think these observations are important
15 in the sections. I think if you have qualitative
16 observations of that nature, they should be there.
17 Because I mean this report doesn't only interest the
18 fire community. I think it interests a larger
19 community including the PRA community or engineering
20 community that needs this kind of information to
21 understand why we're comparing side by side.
22 When I look at the table 3-1 and the
23 results, I become very critical of the spreadsheets,
24 and the comments, in fact, of the text are pretty
25 critical, too. When I hear a comment like that about

1 "but these are the most important parameters and the
2 spreadsheets can't calculate those", those are
3 insights that should be provided in the results. And
4 I think there are others that could be provided there.
5 Just a comment for the record.
6 MR. DREISBACH: Okay.
7 MR. APOSTOLAKIS: Are you skipping --
8 MR. DREISBACH: Yes, because those two
9 slides are going to be talked about more extensively
10 with the next presentation, so I'll just skip over
11 those for the time being.
12 MR. APOSTOLAKIS: So you're going to slide
13 20.
14 MR. DREISBACH: Twenty. Talk a little
15 bit. We've talked about this briefly already, using
16 the results. So what we realize is the scenarios can
17 be described in terms of the physical environment and
18 the phenomenon of interest. That's an important thing
19 that we brought down with us. So what we attempted to
20 do was translate the characteristics and phenomenon
21 from the real scenarios into the common language.
22 that's where we get the normalized or non-dimensional
23 parameters. And then we compare those parameters. We
24 recommend the user compare those non-dimensionalized
25 parameters from his scenario with the ones that we

1 calculate for the experimental scenarios.

2 And I show here two of the examples of our

3 non-dimensionalized or normalized parameters. The one

4 on the left, Q^d-star is a characteristic heat release

5 rate or energy release form a fire. That's normalized

6 by size, diameter. The one on the right up at the top

7 is a ventilation parameter, and it describes or

8 characterizes a burning rate or the availability of

9 oxygen to sustain a fire.

10 MR. BANERJEE: Which one is this?

11 MR. DREISBACH: The one on the right. The

12 phi. And in the lower one, the D-star is another

13 characteristic energy release rate that's used to

14 normalize a height of a room or a more physical

15 characteristic of the room.

16 MR. BANERJEE: What is "r" there?

17 MR. DREISBACH: R is the stoichiometric

18 ration. These are just examples. There are a few

19 more normalized parameters that we have, and they're

20 described further on. And we can talk about --

21 MR. BANERJEE: Well, how do you estimate

22 Q dot?

23 MR. DREISBACH: Q dot is measured by the

24 experiment.

25 MR. BANERJEE: But Q dot is the heat

1 release rate per unit volume, per unit time?

2 MR. DREISBACH: Kilowatts.

3 MR. BANERJEE: Oh, kilowatts. Just total.

4 MR. DREISBACH: For watts.

5 MR. BANERJEE: Total heat release?

6 MR. DREISBACH: Exactly.

7 MR. BANERJEE: So how do you estimate that

8 a priori? I mean if these are non-dimensional groups

9 that you will use to classify scenarios?

10 MR. DREISBACH: Yes.

11 MR. BANERJEE: Q dot is a dependent

12 variable?

13 MR. JOGLAR: This is Francisco. That is

14 depending on your specific scenario, and there are

15 guidance like the Fire PRA guidance that recommends

16 some heat release rate values to use when you're

17 analyzing scenarios. So that's an input for a

18 specific application.

19 MR. BANERJEE: But imagine you're using a

20 code like FDS or whatever, Q dot is part of the thing

21 that you calculate?

22 MR. DREISBACH: No.

23 MR. BANERJEE: It's an input?

24 MR. DREISBACH: It's an input.

25 MR. APOSTOLAKIS: Don't you have --

1 MR. BANERJEE: Don't you have combustion
2 a priori.
3 MR. APOSTOLAKIS: Yes.
4 MR. McGRATTAN: Let me address that.
5 MR. BANERJEE: That's strange.
6 MR. APOSTOLAKIS: Speak to the microphone.
7 MR. McGRATTAN: This is Kevin McGrattan.
8 FDS is used for those types of applications. For
9 example, engineers could use FDS to predict the
10 burning of this room. And it will predict the spread
11 of the fire and so forth. But those types of
12 applications were not included in this V&V exercise.
13 So in this V&V exercise, all of the models used a
14 specified heat release rate. That's not to say that
15 the models can't make a prediction. FDS does make
16 predictions of heat release rate, but in these
17 exercises, all of the heat release rates were
18 specified.
19 MR. BANERJEE: So what you do as input
20 then is the heat release rate and the radius of the
21 fire or whatever?
22 MR. McGRATTAN: Correct.
23 MR. BANERJEE: So these are input
24 parameters?
25 MR. McGRATTAN: These are input

1 parameters, yes.

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

3 MR. DREISBACH: In this analysis, that's

4 what --

5 MR. BANERJEE: So all you really do is the

6 fluid dynamics part of it.

7 MR. McGRATTAN: That's right. Mass and

8 heat transfer throughout the compartment, transport.

9 Primarily transport.

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

11 MR. McGRATTAN: Yes.

12 MR. BANERJEE: The propagation of the fire

13 itself is not taken care of?

14 MR. McGRATTAN: Right.

15 MR. BANERJEE: So if I go one step back,

16 somebody's interested in a fire resulting from

17 spilling of 100 gallons of diesel oil in some

18 compartment, how would they go to step one in your

19 model?

20 MR. DREISBACH: They need to estimate the

21 heat release rate of that spill.

22 MR. BANERJEE: How would they know that?

23 MR. NAJAFI: This is Bijan Najafi. In one

24 of the later slides, in the summary of the results,

25 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

1 be a function of the fluid dynamics.

2 MR. NAJAFI: But it does change. I mean

3 Kevin can explain. We put in an intensity --

4 MR. BANERJEE: Excuse me. I'm asking a

5 straightforward question. I know you put in an

6 intensity. I'm saying that intensity is a function of

7 the fluid mechanics, so how do you decouple them?

8 It's a straightforward question.

9 MR. McGRATTAN: It is a straightforward

10 question.

11 MR. BANERJEE: And it needs a

12 straightforward answer.

13 MR. McGRATTAN: And a lot of this gets

14 into how these models are used in practice. And I can

15 tell you my experience with fire protection

16 engineering community who use FDS, they basically use

17 it in two different ways. One, they use it for a

18 design problem, in which case the AHJ, that might be

19 the fire marshal, he simply says, here's my shopping

20 mall; we have a little McDonald's over here in this

21 area; I'm going to assume that that McDonald's flashes

22 over, that it becomes a fully engulfing fire; I'm

23 going to estimate that that kind of fire is going to

24 produce 20 megawatts of heat; you tell me when the

25 sprinkler is going to activate somewhere down the

1 hall. That's a design consideration. Okay? The
2 engineer is not being asked to predict how that fire
3 starts in the McDonald's or how it spreads in the
4 McDonald's. He's really interested in knowing, worst-
5 case scenario, that whole McDonald's is lost, can I
6 get the people out of the shopping mall. So that is
7 a typical use of the model for design. And in that
8 case, the FDS user would simply dial in the 20
9 megawatts of energy. He wouldn't go to the effort of
10 trying to predict exactly how that fire would spread.
11 MR. APOSTOLAKIS: You're talking nuclear
12 compartments though. I mean you don't assume that the
13 whole thing is --
14 MR. McGRATTAN: Of course, this is just an
15 example. This is just an example.
16 MR. BANERJEE: But, in general, the
17 intensity of your fire depends on oxygen delivery.
18 That's also a factor that enters into it.
19 MR. McGRATTAN: Right. But in that design
20 application, the engineer is being told by the
21 authority: "I think the heat release rate from the
22 fire is going to be this." And that is what Francisco
23 was saying. Oftentimes, in nuclear design, the
24 engineer is told that this cabinet or this pump is
25 going to produce x amount of kilowatts or megawatts.

1 A lot of times that number comes from an experiment.
2 It's difficult for a fire model to predict, to
3 outright predict what the heat release rate is going
4 to be from a burning piece of equipment or the oil
5 spill that you referred to.
6 MR. BANERJEE: Well, presumably --
7 MR. McGRATTAN: So you often get that
8 number from an experiment, and then you put it into
9 the fire model. And the fire model is only expected
10 to do the smoke and heat transport.
11 MR. BANERJEE: But the experiment, whether
12 it's done in a small room or a large room, whatever,
13 you know, the shape and size, the turbulence, I mean
14 it's very dependent on all these factors. And we know
15 that for example -- I know more about explosions --
16 but the propagation between compartments, for example,
17 if you go through a pipe, you change the diameter of
18 the pipe, you get a different heat release rate.
19 MR. McGRATTAN: Exactly.
20 MR. BANERJEE: Completely.
21 MR. McGRATTAN: Exactly.
22 MR. BANERJEE: Due to the turbulence. So
23 how is it that this experiment gives you this value,
24 then becomes enshrined in this way and serves as an
25 input to this model. I mean then what are we talking

1 about? There's a huge uncertainty in that experiment
2 itself.
3 MR. McGRATTAN: Right. And that's a good
4 lead in for Anthony Hamins' talk, because he's going
5 to talk about how the uncertainty in the heat release
6 rate propagates through the model. Because oftentimes
7 when you're talking about the uncertainty in the model
8 predictions, the key uncertainty is not the model
9 itself but rather the input data. Does that cabinet
10 produce one megawatt or two megawatts. That often
11 becomes a much bigger issue than the model itself.
12 MR. BANERJEE: But there's an interaction
13 between the model and the heat release rate.
14 MR. McGRATTAN: Right.
15 MR. JOGLAR: This is Francisco. Something
16 that has not been mentioned is heat release rate in a
17 practical application we put it as an input. Zone
18 models and field models will, however, use that input
19 and maybe modify it, depending on the conditions that
20 are generated in the room, like the amount of oxygen.
21 So they modify that. But the initial profile is an
22 input. And depending on what's developed in that room
23 with the size that we put in and the ventilation
24 conditions, it can be modified.
25 MR. BANERJEE: So you do modify it then or

1 you do not?

2 MR. McGRATTAN: Yes, these models have

3 built into them oxygen limitation, so if we're given

4 a specified heat release rate, oftentimes what that

5 really means is we're given a specified burning rate.

6 And then the model will determine if or if not there's

7 enough oxygen in the room to actually consume all of

8 the fuel that's being liberated.

9 But the prediction of the burning rate for

10 most practical items is very difficult for the model

11 to do. There's too much uncertainty and practice in

12 the nuclear community and in the non-nuclear community

13 is usually to burn the item of interest, get its heat

14 release rate and specify it in the model. Now

15 oftentimes when you burn the item, you burn it in

16 similar conditions. So if you're interested for

17 example in the heat feedback, you often burn, for

18 example, under some hood that will get hot and then

19 radiate backwards.

20 When we did work on the World Trade Center

21 and how that building collapsed, we did a lot of

22 experimental work in which we placed the items of

23 interest, typical office furnishings, underneath a

24 steel hood. That steel hood was allowed to get hot,

25 and what we wanted that hood to do was represent a

1 real fire environment in which the burning rate of the
2 fuel is not just dependent on the fire itself but
3 rather the hot gas layer above. So we try as much as
4 possible, when we get these burning rates and heat
5 release rates, to burn the item in an environment that
6 is consistent with what that item would actually see
7 in the real plant.
8 MR. BANERJEE: But in fact, I mean don't -
9 - your model, the tables you're showing natural
10 ventilation and mechanical ventilation. You're
11 actually charging whether or not your mechanical
12 ventilation and natural ventilation as characteristics
13 fit into the test, so you're considering those?
14 MR. McGRATTAN: Yes.
15 MR. BANERJEE: Right? I mean I'm looking
16 here at this table.
17 MR. DREISBACH: In the experiments that we
18 evaluate, we characterize the ventilation conditions
19 and that is evaluated against the ventilation
20 conditions in the real scenario, yes.
21 MR. BANERJEE: I suppose what we're saying
22 is Q dot depends on FIVE?
23 MR. DREISBACH: Sure. Yes.
24 MR. McGRATTAN: Right. And in fact, Q dot
25 is often limited by FIVE. At some point you cannot

1 get any more heat out of an under-ventilated room.

2 MR. KHALIK: I guess on a more basic

3 level, Q dot is a dependent variable rather than an

4 independent variable?

5 MR. McGRATTAN: It depends on how you're

6 doing your analysis.

7 MR. KHALIK: Well, it depends on -- I'm

8 talking about in real life.

9 MR. McGRATTAN: Oh, in real life,

10 absolutely.

11 MR. KHALIK: Q dot is a dependent variable

12 depending on the geometry and boundary conditions.

13 MR. McGRATTAN: Right.

14 MR. KHALIK: And you are using it as an

15 independent variable and perhaps you're using it sort

16 of in a parametric iterative fashion until things fit

17 together. Then you know you have the right Q-dot.

18 MR. McGRATTAN: Right.

19 MR. KHALIK: Is that the process.

20 MR. McGRATTAN: Yes. We're quite

21 confident that these models do smoke and heat

22 transport very, very well. However, we're still not

23 at a point where we can make outright blind

24 predictions of burning rates of common materials. We

25 would much rather get experimental data for the source

1 term and put that into the model rather than have the
2 model try to determine that automatically.
3 MR. PEACOCK: That has been the Holy Grail
4 of fire research for at least 20 years to be able to
5 do that.
6 MR. BANERJEE: But at least to a first
7 approximation, it should be made a function of fire
8 something, right, in the sense that you may have a
9 burning rate with plenty of oxygen and parametric
10 crises, and then as you decrease oxygen, the burning
11 rate will change.
12 MR. McGRATTAN: Right. And oftentimes our
13 experiments, to characterize the burning rates of
14 objects, are done inside and outside of rooms. So we
15 often want the heat release rate, for example, of a
16 sofa -- I'm talking more in residential applications -
17 - underneath a hood with plenty of ventilation. We
18 also will put that sofa into a small compartment to
19 represent a living room and get the burning rate
20 there. And then we compare, and we see what the
21 oxygen limitation, how that's having an affect on the
22 burning rate.
23 MR. KHALIK: My concern about this process
24 is that the user of code of this type can get whatever
25 answer he or she wants.

1 MR. McGRATTAN: Which is why the heat
2 release rate is often specified by the AHJ. Go back
3 to the McDonald's analogy. Lots of tests have been
4 done on fully flashed-over fires in compartments.
5 They have a fairly good idea of what the upper bound
6 in the heat release rate is going to be. They'd
7 rather use that, that upper bound, for a conservative
8 analysis rather than let the fire modeler try to
9 predict what the heat release rate is going to be.
10 MR. APOSTOLAKIS: But that's for design
11 purposes of structures that are not subjected to ACRS
12 review.
13 MR. DREISBACH: Anthony is going to talk
14 more about --
15 MR. APOSTOLAKIS: In the early PRAs, we
16 did what Professor Banerjee just suggested. We
17 calculated the heat release rate, and we considered
18 cases when it was ventilation controlled in the first
19 approximation or not. So it's not something new. It
20 was done then. It was calculated, you know, in the
21 early code. So it doesn't seem to me that it would be
22 such a big deal to do that. So you guys keep saying
23 it's an input. I mean we calculated it. The biggest
24 uncertainty was there, of course. The mass burning
25 rate is really very much uncertain.

1 MR. JOGLAR: Well, the -- a quibble into
2 what Kevin said about the McDonald's, that heat rate
3 is prescribed. There are documents that prescribe
4 heat release rates for nuclear applications, and we
5 have to --
6 MR. APOSTOLAKIS: Where? Where are these
7 documents?
8 MR. JOGLAR: 6850 has a table of what
9 numbers to use.
10 MR. NAJAFI: Appendix E. And the basis
11 for it was experiments were conducted to the extent
12 possible to mimic the nuclear power plant and
13 electrical fires. Basically, you're correct. When
14 you build - an initial intensity is driven by the
15 amount of fuel you have, fuel package inside a panel,
16 for example, for electrical, how much ventilation you
17 have, what's the configuration of the fuel, how
18 tightly it's combined, and how it's vented and all of
19 that kind of stuff. So we created something. They
20 created. Sandia National Lab, they created something
21 similar to that and burned it and measured it to get
22 the mass loss rate. And from that mass loss rate, we
23 came up with these distributions that says this is the
24 90 through some method. So it's documented. That's
25 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?

1 MR. DREISBACH: -- based on my scenario.
2 Whatever your prediction shows. That's the point.
3 You as a user are providing information to the NRC as
4 the reviewer to prove something or other.
5 MR. APOSTOLAKIS: Which model, though? I
6 mean you're evaluating five models.
7 MR. DREISBACH: Yes.
8 MR. APOSTOLAKIS: Which model am I
9 supposed to use.
10 MR. JOGLAR: The model is the one in the
11 list of cores that you say that are listed, that has
12 the capability to make a calculation and has our
13 judgment, this team's judgment on how good that
14 calculation is. So if you pick out of that table to
15 calculate a capability with one of those models, then
16 you have to check that your dimensionalized parameters
17 match the ones that we did for these experiments.
18 MR. APOSTOLAKIS: That's where you lose
19 me.
20 MR. DREISBACH: This is not providing you
21 the decision to choose one model over another. You
22 have to make that decision using this, using other
23 tools, using the scenario, evaluating your scenario.
24 You make the decision about what model you choose.
25 You then take the information from your model and your

1 scenario, evaluate it against our validation range,
2 and then you're able to use some of the conclusions
3 from the results of this report.
4 MR. APOSTOLAKIS: But, again, this is a
5 simple thing. I'm trying to understand. I'm
6 interested in the hot gas layer temperature.
7 MR. DREISBACH: Okay.
8 MR. APOSTOLAKIS: You're table 31 tells me
9 that CFAST, MAGIC and FDS are green.
10 MR. DREISBACH: Yes.
11 MR. APOSTOLAKIS: FIVE and FDT are yellow.
12 MR. DREISBACH: Within the ranges on the
13 right-hand side, that's the colors that you get.
14 MR. APOSTOLAKIS: Wait. So I'm saying
15 okay, I'm going to go with one of the three greens,
16 CFAST for example. Then the next step is for me to
17 calculate all these dimensionalized parameters for my
18 problem --
19 MR. DREISBACH: Yes.
20 MR. APOSTOLAKIS: -- and come to this
21 slide 21 to decide whether I can actually use CFAST?
22 MR. DREISBACH: Whether you can make
23 conclusions based on this validation about CFAST and
24 your prediction.
25 MR. APOSTOLAKIS: What conclusions are

1 these?

2 MR. NAJAFI: Well, basically once you

3 decided that all of those codes are green, you chose

4 the CFAST.

5 MR. APOSTOLAKIS: Yes.

6 MR. NAJAFI: Then you come to this table.

7 This table tells you that if you're within .4 and 2.4,

8 you are allowed to use the green. But if you're .1,

9 you're not allowed to use the green.

10 MR. DREISBACH: You have to -- there's a

11 level of confidence that you can use CFAST for that

12 particular scenario.

13 MR. APOSTOLAKIS: How many of these

14 parameters am I supposed to calculate and come to the

15 table, just one?

16 MR. JOGLAR: It depends on each case. It

17 depends on the characteristics of each fire scenario.

18 If it's, for example, a small room where ventilation

19 can be critical.

20 MR. APOSTOLAKIS: A hot gas layer in a

21 small room.

22 MR. JOGLAR: Oh, then the heat release,

23 maybe the phi, the --

24 MR. APOSTOLAKIS: B? Okay. Is it

25 possible that 2*d* is 2.1 but phi is 1, so I'm having

1 a problem now?

2 MR. DREISBACH: Yes.

3 MR. APOSTOLAKIS: One is within the other

4 result?

5 MR. DREISBACH: Yes.

6 MR. APOSTOLAKIS: So what do I do?

7 MR. JOGLAR: Well, it means, I think, that

8 you can estimate 1, but not the other. I mean it

9 falls outside of the V&V, right?

10 MR. DREISBACH: Right.

11 MR. APOSTOLAKIS: No, but this is

12 ridiculous.

13 MR. BONACA: It depends on the

14 applicability of the scenario.

15 MR. APOSTOLAKIS: That's where I'm lost

16 now. I want the hot gas layer temperature. That's

17 what I want.

18 MR. DREISBACH: Yes.

19 MR. APOSTOLAKIS: Everything else is

20 input.

21 MR. JOGLAR: But we have to bound the

22 scope of this V&V, because it's not a blanket for

23 every single application.

24 MR. APOSTOLAKIS: My question is really

25 very simple, unless I'm not posing it -- I choose

1 CFAST. I want the hot gas layer temperature. You
2 just told me I need to calculate for my room 2*d* and
3 phi, right?
4 MR. JOGLAR: Yes.
5 MR. APOSTOLAKIS: 2*d* is 2.1. Phi is 1.
6 What am I supposed to do?
7 MR. BANERJEE: Nothing. It's outside the
8 range of the validation.
9 MR. APOSTOLAKIS: Then what?
10 MR. DREISBACH: You can do any number of
11 things. You can make statements regarding why the phi
12 of 1 is still okay based on your scenario versus our
13 scenarios. You have to make an argument why we or a
14 regulator should accept the analysis if one is outside
15 the range.
16 MR. BANERJEE: Yes. And you would
17 calculate that the hot gas layer. All this is saying
18 is this V&V doesn't provide validation for that
19 calculation.
20 MR. APOSTOLAKIS: So I'm left alone in the
21 wilderness to face the NRC then?
22 MR. DREISBACH: Well, you're not alone.
23 MR. APOSTOLAKIS: Well, there will be
24 other people who will say in public. Okay. But then
25 -- okay. Now another question. Is it really -- I

1 mean these models, again, CFAST, it did not predict --
2 let's use that word -- the results of each one of
3 these experiments equally well. Some of them were
4 better than others?
5 MR. DREISBACH: Yes.
6 MR. APOSTOLAKIS: So is it reasonable then
7 to take the widest, the lowest bound of the range or
8 the upper bound from all these experiments? I mean
9 what if the best fit was Experiment B#5, which is .7,
10 and yet you're telling me now that for CFAST the range
11 is .4 to 2.4? Aren't you eliminating some of the
12 detail here that may be important?
13 MR. DREISBACH: The detail is coming
14 later. This is just we're trying to describe the
15 process. What happens is we use the model to
16 calculate all the experiments, and we summarize the
17 data in a set of graphs that we call scatter plots
18 that provide an indication of the measured
19 temperature, we'll say, and the calculated
20 temperature. And we use judgment based on a metric as
21 far as uncertainty is concerned to determine the level
22 of confidence in that range. So there may be points
23 in that range that are not as good as points from
24 another experiment. But --
25 MR. APOSTOLAKIS: But it's still green?

1 No, green is based on something else.

2 MR. DREISBACH: Because they're all within

3 a certain metric of uncertainty. That provides us --

4 MR. PEACOCK: But there may be other

5 quantities. For example, it gets a yellow because

6 it's good in one area but not so good in another area.

7 MR. JOGLAR: The colors are our best

8 judgment on this based on all the calculations, and I

9 wouldn't dismiss the situation in which a

10 knowledgeable user could point out the best experiment

11 that fits his case and use that range for a

12 dimensional experiment. That's why all of them are

13 liste there, but that requires big knowledge of how

14 the experiment was wrong. And that information we

15 also provide.

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

17 then.

18 MR. KHALIK: This turning point for a lot

19 of this is that the user has to verify that the

20 parameters associated with the scenario in which he or

21 she is interested fall within these ranges.

22 MR. DREISBACH: Yes.

23 MR. KHALIK: And if I look at these

24 parameters, Q^{d*}, phi and h over d*, those are the

25 three parameters for which you had a range that the

1 user has to verify fall within these ranges.

2 MR. DREISBACH: There a few more in the

3 report.

4 MR. KHALIK: But all of these parameters

5 have Q dot in the definition.

6 MR. DREISBACH: Yes.

7 MR. KHALIK: And Q dot is an assumed

8 number, and therefore the user can essentially force

9 the scenario to fall within the validation range by

10 assuming whatever value of Q dot that would satisfy

11 these criteria. So it seems like --

12 MR. DREISBACH: It's prescribed, though.

13 MR. KHALIK: -- the user can sort of get

14 whatever answer he or she wants for the scenario.

15 MR. NAJAFI: That I guess goes back to the

16 question -- this is Bijan Najafi -- that Apostolakis

17 was asking, and I was trying to say that in some other

18 document that NRC and EPRI had developed, there is

19 guidance of how to select a Q dot for a particular

20 scenario. It's not left to the user if they follow

21 that document. Of course, anybody can use outside.

22 But there is guidance out there that is developed by

23 this collaboration between -- it is -- specifically

24 Table E-1 in the NUREG-6850 for example says if you

25 have a vertical cabinet with qualified cable with a

1 single bundle which prescribes how the cabinet
2 geometry ventilation is formed, you have to use a heat
3 release rate that ranges between 70 to 211 kilowatts.
4 And it says the basis of it is Sandia test number
5 umptysquat, that it was done with this similar
6 geometry. So it's not that we leave it out there for
7 a user to pick whatever term they want to dial in.
8 That's part of the generating, and defining the
9 scenario is to characterize the initial source.
10 Intensity is one of the things. There are other
11 things associated with it, but the characterization,
12 there is guidance out there.
13 MR. HYSLOP: Yes. This JS Hyslop from
14 NRC. I guess I was the NRC sponsor to 6850. The
15 initial conditions, the heat release rates which are
16 used in these cases, you know, as Bijan says, there
17 are single cable bundles, multiple cable bundles, and
18 electrical cabinets. There is a distribution for each
19 one of those. And not only were they based on Sandia
20 data, they were based on data from other tests as
21 well. And so the people developing this distribution,
22 it was a process where they took into consideration
23 the data that was available for these particular types
24 of ignition sources. And that's documented in 6850.
25 MR. DREISBACH: So in many cases, the heat

1 release rate is prescribed ahead of time.

2 MR. KHALIK: But does that cover all

3 scenarios in which a user is interested. Let's say

4 again the sample of spilling 100 gallons of diesel oil

5 in an area that is 5 square meters with a sort of an

6 edge that's 6 inches high?

7 MR. JOGLAR: Yes, it does. Yes, it does.

8 Because for your specific example of a pool fire,

9 there are clearly specified equations to do that, I

10 mean that are well defined and documented. So for

11 most I would say yes. I mean there may be where we

12 don't know, and it's up to an engineering judgment at

13 the moment and the review process to determine if --

14 MR. APOSTOLAKIS: So am I to understand

15 then that for most of the scenarios to which these

16 models apply in nuclear plants the parameters, these

17 measurements, parameters will fall within the range or

18 the majority, or you don't know?

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

20 MR. DREISBACH: I would not --it's hard to

21 say the majority.

22 MR. APOSTOLAKIS: So what do we do then?

23 MR. BANERJEE: You cannot use that

24 scenario for validation of the parameter. That's the

25 way I understand it, right?

1 MR. APOSTOLAKIS: No, no, no. It's the
2 other way. I want to use a code to do my PRA in
3 support of NFPA 804 -- 5, 4, whatever -- 5. And I'm
4 preparing my case to come, and I know NRR will review
5 it.
6 MR. PEACOCK: Then you have to -- it's --
7 if it falls outside the validation results that are
8 provided here or additional ones in the future, that
9 implies that there is additional work that you would
10 have to do in terms of providing justification that
11 the model was valid to use here. That may be
12 additional test results. That may be additional model
13 comparisons with those test results that says that the
14 model is appropriate for the scenario I'm interested
15 in.
16 MR. BONACA: For example, the volume of
17 the test and the volume of the room in which the test
18 was done or some other parameters, like ventilation,
19 et cetera, maybe so different from what you are trying
20 to apply it to that he cannot use this comparison for
21 validation. They're telling you you're out of the
22 range of this parameter which is a member -- I mean
23 the dimension of this parameter, but that will give
24 you the guide that says yes, --
25 MR. DREISBACH: The analysis is obviously

1 limited.

2 MR. BONACA: -- you can use it for

3 validation, this parameter, but you cannot use it for

4 validating the other parameter. So maybe you can use

5 it only for validating flux but not hot gas.

6 MR. BANERJEE: I have a much more

7 fundamental problem. How did we pick these non-

8 dimensional groups, and are they actually the ones

9 that are important? I mean I think we should get back

10 to basics on that, because we are asked to accept this

11 as being the -- I haven't seen any justification for

12 these groups.

13 MR. BONACA: - the way I understood what

14 they were doing. Okay? Now that's a different

15 question.

16 MR. APOSTOLAKIS: Before we go to Sanjoy's

17 point, Mario, realistically now, somebody's doing a

18 Fire PRA and he falls outside, do you really think

19 they're going to go and run tests?

20 MR. BONACA: No.

21 MR. BANERJEE: No, of course not.

22 MR. BONACA: No.

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

24 issues --

25 MR. APOSTOLAKIS: In fact, most of the

1 analyses we have seen from the industry are using
2 FIVE.
3 MR. BONACA: But we heard a comment here
4 that said well, you have all those n/a's that you can
5 now run the test. That's if I understand it.
6 However, you get the most important parameters even
7 with those, so therefore, you know, why worry about
8 that. Probably for a PRA, you would be satisfied with
9 having those parameters, flame height, plume
10 temperature. I'm trying to say that you --
11 MR. APOSTOLAKIS: Well, the point --
12 MR. BONACA: -- be able to use that.
13 MR. APOSTOLAKIS: I understand, but my
14 point also from the practical point of view is that
15 nobody will go out and do those things, because nobody
16 can afford it. It's true that most of the industry
17 PRAs we have seen, or the IPEEEs were FIVE, right?
18 And here is an interesting statement. The libraries
19 of engineering calculations, FTT5-Reg 1 have limited
20 capabilities. These libraries do not have appropriate
21 methods for estimating many of the fire scenario
22 attributes evaluated in this study. Now what do I do?
23 I don't know what to do.
24 MR. BANERJEE: Well I think, though, there
25 is a point of view where if you have a well-validated

1 tool like your FDS or something, it doesn't strictly
2 have to stay within the parameter range because there
3 is some science there now. It's not just purely
4 empirical. So in a sense, we do this all the time in
5 terms of other things where we do experiments on a
6 scale which is smaller, and we use a computer to try
7 and bridge the gap to full scale where we don't have
8 any experiments. So I think the more strong the
9 science base for a tool is, the better chance you have
10 --
11 MR. APOSTOLAKIS: Absolutely.
12 MR. BANERJEE: -- to be able to go outside
13 the precise range of the parameters. I have much more
14 concern, though, with the parameters which actually go
15 into this, like the --
16 MR. APOSTOLAKIS: I just thought about
17 that.
18 MR. BONACA: -- heat import and the non-
19 dimensional groups and things like that.
20 MR. McGRATTAN: I'll address that. These
21 parameters simply fall out of the Navier Stokes
22 equations when you non-dimensionalize them,
23 specifically for fire applications. For example, the
24 2* is basically a Froude scaling. D* is basically the
25 characteristic diameter of the fire. So all of these

1 people who are doing pool fire experiments, for
2 example, which is nothing more than a circular pan
3 filled with fuel. You're measuring center line,
4 temperatures and velocities. You take the Navier
5 Stokes equation, non-dimensionalize. These are the
6 parameters --
7 MR. BANERJEE: But I don't see a Grashof
8 number there. I would have expected a Grashof number
9 rather than a Froude number. How is that happening?
10 I mean when I non-dimensionalize the Navier Stokes
11 equation for a flow, I tend to get the Grashof number.
12 MR. McGRATTAN: Right.
13 MR. BANERJEE: So there is none here.
14 MR. McGRATTAN: I don't think we've gone
15 through all of them. I mean we could sit down and go
16 through them but --
17 MR. BONACA: Sit down and non-
18 dimensionalize the Navier Stokes. Generally, I would
19 get in a buoyancy-driven system, a Grashof number.
20 Said will correct me if I'm wrong, but I don't see
21 that number.
22 MR. McGRATTAN: Right. And the reason why
23 you're not seeing it here is because most of these
24 models and these non-dimensional quantities are just
25 for mass and energy conservation. Remember CFD is

1 relatively recent and actually, doing these plume
2 calculations is a recent phenomena. So I focus on
3 Grashof numbers and such, but the traditional models,
4 the hand calcs and the zone models don't have a use
5 for that. They have a use for characterizing the
6 geometry of the space and the size of the fire,
7 because at the end of the day when you're using a hand
8 calc or you're using a zone model, that's what you're
9 considering. Now when you're getting into the CFD,
10 that's when you're getting into the dynamics of the
11 flow. And then there are other parameters that come
12 into play. For example, D*, for me, is the most
13 critical parameter, and yet none of other models
14 really have a need for it. D* is the characteristic
15 diameter of the fire. And when I choose a numerical
16 grid, I need to get, you know, x number of cells
17 across that fire to really resolve all the eddies and
18 so forth. So it depends on the application.
19 MR. BANERJEE: I'm also concerned that if
20 you're doing mass and energy balances for these two-
21 zone models, how does G come into it?
22 MR. McGRATTAN: G comes into it via --
23 MR. BANERJEE: That's simple dynamics.
24 MR. McGRATTAN: -- a plume correlation.
25 A zone model has no flow field. What it has is a

1 correlation that says for a fire of a certain size,
2 you have so much entrainment of air which pumps air
3 from the lower layer into the upper layer. So you
4 have transport of a certain amount of mass and heat
5 from cold zone to hot zone.
6 MR. BANERJEE: So you're trying to --
7 MR. McGRATTAN: So it's a correlation.
8 MR. BANERJEE: -- apply the Navier Stokes
9 in some way?
10 MR. McGRATTAN: So the Navier Stokes are
11 simply bundled into that correlation which is pulled
12 from the experimental literature --
13 MR. BANERJEE: It doesn't come out of the
14 equations?
15 MR. McGRATTAN: No, no, no.
16 MR. BANERJEE: It comes out of it?
17 MR. McGRATTAN: No. You pretty much throw
18 the momentum equation away when you're dealing with
19 the hand calcs and the zone models. That momentum
20 equation only shows up when you look at pressure
21 differentials and so forth.
22 MR. BANERJEE: So there are two scenarios?
23 MR. McGRATTAN: Yes.
24 MR. BANERJEE: One which is sort of
25 understandable is whatever non-dimensional groups

1 arise by non-dimensionalizing the conservation
2 equations for the sort of calculation that FDS is
3 doing.
4 MR. McGRATTAN: Right.
5 MR. BANERJEE: Well, I would expect that
6 these groups are wrong, because they are not -- they
7 would have other numbers. If I non-dimensionalize
8 them, I won't get these numbers.
9 MR. McGRATTAN: Right.
10 MR. BANERJEE: I actually went through
11 your report on the equations. Okay? So if on the
12 other hand you are using a more approximate model,
13 then these non-dimensional groups are arising out of
14 some empirical correlation for whatever the dynamics
15 are. So in that case, it is required that we justify
16 these are necessary and sufficient number of groups
17 that we are using if this is going to be actually
18 given as guidance?
19 MR. McGRATTAN: Right. If you talk to
20 some of the people who have been around for a long
21 time, like for example Jim Quintiere, what happened
22 was he noticed when he started collapsing his data
23 trying to develop these correlations, he started
24 seeing these groups pop out of his analysis, just
25 purely empirically. At the same time, the fluid

1 mechanicians were getting into it, starting to study
2 the plumes, starting to develop CFD models. They were
3 non-dimensionalizing. And lo and behold, these two
4 groups came together at some point and said, these
5 parameters, the Q*'s, the D*'s, we're seeing the same
6 thing. We're looking at the same non-dimensional
7 parameters coming from the empirical community and
8 coming from the theoretical side. That's what gives
9 me confidence that these are the parameters that we
10 want to focus our attention on, that coincidence, if
11 you will, of the theoretical and the empirical.
12 MR. BANERJEE: Is the science-base for
13 choosing this documented somewhere in a -- I would say
14 this is fairly critical, because you're asking people
15 to be guided by the choice of these within a certain
16 parameter range?
17 MR. McGRATTAN: The best documentation for
18 this is what's called this SFPE Handbook, the Society
19 of Fire Protection Engineers Handbook. And what that
20 is nothing more than the history of fire research, and
21 article after article after article, whether you're
22 looking at ceiling jets, plumes, and whatever else,
23 these parameters come up again and again and again.
24 I mean it's hard to say these are the right ones and
25 these are the wrong ones, but these are the parameters

1 that have stood the test of time. They have a
2 theoretical basis. They also have an empirical basis.
3 That's what gives me that level of confidence, because
4 they come from the two worlds that we often deal with
5 in fire.
6 MR. BANERJEE: Well, I think it's a
7 critical issue to document. I mean in a sense, what
8 you're saying is you have to read a whole handbook to
9 get this feeling of comfort which --
10 MR. McGRATTAN: Well, you can read --
11 Quintiere's written a book on fire. Dougal Drysdale.
12 There are a number of experts in the field who have
13 written textbooks documenting these parameters. The
14 Handbook I mentioned simply because it's something
15 that we all use. We all have it on our desks.
16 MR. APOSTOLAKIS: Can you address this
17 issue maybe using a couple of slides at the
18 presentation to the full committee?
19 MR. McGRATTAN: Sure.
20 MR. APOSTOLAKIS: And maybe give a
21 specific reference that some of us who are interested
22 can go and read without reading the whole Handbook.
23 MR. BANERJEE: We can't be experts at
24 everything, right.
25 MR. McGRATTAN: Absolutely. I mean --

1 MR. BANERJEE: We can't, but George can
2 very quickly.
3 MR. McGRATTAN: We can have a lecture on
4 the history of fire dynamics, fire research.
5 MR. APOSTOLAKIS: Well, not the history.
6 Please. There is a straightforward question. Provide
7 some of the scientific bases. Now you might want to
8 say, you know, in 1956, this was done, this and that.
9 MR. McGRATTAN: Right.
10 MR. APOSTOLAKIS: But at least give a more
11 specific answer to this question.
12 MR. McGRATTAN: Right. We can do that.
13 MR. APOSTOLAKIS: I think that will be
14 very useful.
15 MR. JOGLAR: Yes. Jim Quintiere last year
16 published a book. We went this year with a full
17 chapter on these dynamics.
18 MR. APOSTOLAKIS: Francisco, I have no
19 doubt that you guys can do it. Okay? But please do
20 it.
21 MR. McGRATTAN: Okay.
22 MR. KHALIK: Does D* appear anywhere in
23 FDT?
24 MR. DREISBACH: D* in the spreadsheet
25 calculation?

1 MR. KHALIK: That's right.

2 MR. DREISBACH: Probably not because it's

3 not an important parameter for that type of mode.

4 MR. KHALIK: Does the ratio page over D*

5 appear anywhere in FTD?

6 MR. DREISBACH: Not in the spreadsheets,

7 no.

8 MR. KHALIK: Does the model or the

9 empirical model contained in FTD or FIVE contain the

10 ratio H over D* as an independent parameter anywhere?

11 MR. DREISBACH: No.

12 MR. KHALIK: And yet you're asking the

13 user not to use that model outside the range of 3.6 to

14 16, correct?

15 MR. McGRATTAN: I guess so.

16 MR. KHALIK: So where is the connection

17 between the constraint that you're imposing on the

18 range of applicability of a model and the dependence

19 of the outcome of the model on that parameter?

20 MR. McGRATTAN: These non-dimensional

21 parameters are used to characterize the experiments

22 that were conducted, so H over D* is basically

23 characteristic height of the entire volume versus the

24 characteristic height of the fire. Okay? Or

25 characteristic height scale of the fire. If H over D*

1 is very, very large, what you have is a man smoking a
2 cigarette in a football stadium. And we'd be hard-
3 pressed to say that we could model or that we could
4 justify the use of these models and these experiments
5 for that scenario.
6 So H over D* is one way that we're using
7 to characterize the experiments. It doesn't have any
8 particular model in mind. It's simply a ratio of two
9 length scales that help to characterize the relative
10 size of the fire to the size of the building. And
11 that does come into play when you're considering
12 whether or not to use this guide.
13 MR. KHALIK: Well, when somebody develops
14 an empirical model, it doesn't come out of thin air,
15 right? It comes out by fitting some set of
16 experimental data, right?
17 MR. McGRATTAN: Right.
18 MR. KHALIK: And therefore, the governing
19 constraint for the use of an empirical model is what
20 is the experimental database that was used to develop
21 that model.
22 MR. McGRATTAN: Right.
23 MR. KHALIK: And now how does the ratio of
24 H over D* for which that empirical model was
25 developed, the experiments that were used to develop

1 that model compare with the set of --

2 MR. McGRATTAN: Well, if you notice in the

3 chart with the colors, the yellow and the green, all

4 those n/a's that you see associated with the FIVE and

5 the FDT, what that means is that those models and the

6 way that they were developed fell outside of the range

7 of parameters of the experiment. So for example, we

8 did an experiment or we looked at experimental data in

9 which we had a large fire in a very small compartment,

10 this so-called pump room example. Well, the ceiling

11 jet algorithms in FIVE and FDT were not appropriate

12 for that experiment, because the ratio of the height

13 to the width fell outside the range for which that was

14 calibrated.

15 MR. JOGLAR: I see it as two layers of

16 verification. This last table is for kind of

17 practical applications but also in our individual

18 volumes, in chapter three, describe the question that

19 is in the spreadsheet, and it says the range of data

20 that was used to develop that correlation. So kind of

21 both of them have to be checked if you have to use

22 that equation. But that information is in there.

23 MR. DREISBACH: We can provide some -- as

24 we said, at the full committee, we'll provide some

25 more background of the non-dimensional parameters, but

1 I'd just like to --

2 MR. APOSTOLAKIS: Yes. I'd like to come

3 back to the schedule here. We absolutely have to

4 finish at 2:30, because we have another presentation

5 after that, and we have planes to catch. And I think

6 you have too much material here to cover, and I

7 definitely want to hear the summary of results and

8 concluding remarks. So maybe you gentlemen can decide

9 to what extent you want -- and also we agreed that you

10 will walk us through one of the models and one of the

11 tests, how you did it. Is that what we said earlier?

12 I thought we agreed.

13 MR. NAJAFI: I think we said we will go

14 through the example of how these color-coded things is

15 going to be used. That's what I heard, but if there's

16 other people --

17 MR. APOSTOLAKIS: Well, not just for the

18 use but also, you know, how did you decide if

19 something is green. Better walk us through the --

20 MR. DREISBACH: Yes. We can show you

21 that.

22 MR. APOSTOLAKIS: So if you want to

23 rearrange your presentations to fit the time

24 available, please do, because I see you have

25 presentation on FTD, on CFAST and FDS. I'm not sure

1 we can do all of that.

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

3 -

4 MR. APOSTOLAKIS: So while you are

5 speaking, maybe Bijan can thing about it, what to cut?

6 MR. DREISBACH: I think one of the key

7 projects and one of the things that we're somewhat

8 proud of is the way we developed our uncertainty and

9 our method --

10 MR. APOSTOLAKIS: Of this presentation?

11 MR. DREISBACH: That's this presentation.

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

13 then.

14 MR. DREISBACH: And that's what we'll go

15 through now. And Anthony Hamins from NIST is going to

16 present that information.

17 MR. APOSTOLAKIS: Well, then think about

18 the rest, what to cut and what to include. Please,

19 identify yourself.

20 MR. HAMINS: I'm Anthony Hamins of NIST.

21 I'll be presenting Volume II of this V&V study that

22 establishes a quantitative evaluation methodology and

23 emphasizes experimental uncertainty. And then

24 following my presentation, my modeling colleagues will

25 present their results of the evaluation using this

1 methodology.

2 So this presentation is broken into

3 several parts. First, I'll describe some of the

4 details of the experiments selected for this

5 validation study. Then I'll describe the methodology,

6 including the role of experimental uncertainty in this

7 process. I'll give examples of the analysis

8 highlighting key fire parameters. And finally, our

9 conclusions will be summarized.

10 This table shows the experiments that were

11 selected. There were 26 tests, 6 experimental

12 configurations. They're listed as shown,

13 chronologically. Four of these tests were

14 specifically designed for nuclear power plant

15 application validation. The first one and then the

16 last three.

17 MR. APOSTOLAKIS: FM is factoring mutual?

18 MR. HAMINS: That's correct, factoring

19 mutual. And then S&L stands for national labs. NBS

20 is the old NIST, National Bureau of Standards. ICFMP,

21 four sets of data were provided by ICFMP. This is the

22 International Collaborative Fire Modeling Project.

23 NRC took a lead role in this. So in these six sets of

24 experimental configurations, NRC really was heavily

25 involved in the first one and the last four. And the

1 reason they're involved in finding good data from all
2 validation is because there is a scarcity of well-
3 documented, comprehensive compartment fire test data
4 available in the scientific literature.
5 MR. APOSTOLAKIS: Well, typically in a
6 nuclear plant, in a compartment, what actually burns?
7 MR. HAMINS: I' going to defer to my
8 colleagues who are experts in nuclear power --
9 MR. APOSTOLAKIS: Because these substances
10 that are burning here, ethanol or the propylene are
11 not typical of what one would expect.
12 MR. HAMINS: That's correct. These are
13 essentially heat sources, fire sources that the intent
14 is to have a well-controlled fire source in order to
15 be able to test the models. Because an essential part
16 of the experimentation and the model comparison is to
17 have a very good knowledge of the heat release rate.
18 Without knowledge of the heat release rate in these
19 steadily burning fires, then the validation, the
20 comparisons would never work, and there would never be
21 a good comparison between models and measurements.
22 We are not at the point where we can
23 predict fire spread from this corner in this room
24 through the building and to the building next door.
25 We're just not there. So in this study we have used

1 steadily burning pool fires typically or spray fires
2 in a well-controlled, regulated manner in order to
3 provide a constant heat release rate for which the
4 models can be compared. So we're looking at the
5 thermal environment of this compartment and how it
6 changes as the fire continues to burn. And we're
7 observing.
8 MR. APOSTOLAKIS: They are surrogates for
9 whatever would be the materials burning --
10 MR. HAMINS: That's right.
11 MR. NAJAFI: Let me add something to it,
12 because there is a little bit more to it than that.
13 For example, the first one, the propylene is the
14 initial trigger of the fire. The actual 500 kilowatt
15 is not coming from that fuel material. they took an
16 electrical panel, a cabinet, a metal cabinet. They
17 loaded it up with cable bundles, some to the tune of
18 about 100,000 megajoules or something. So they took
19 massive cable and put it in there. The propylene or
20 that some kind of fuel trigger was used, because they
21 could not electrically infuse a cable fire. So
22 basically that's what is used to ignite the cable.
23 MR. BANERJEE: Is that true of all of
24 these cases? I mean this is very confusing --
25 MR. NAJAFI: No.

1 MR. BANERJEE: Because I mean if you call
2 it a fuel, we assume propylene is the fuel. You are
3 not saying the fuel is actually the cable.
4 MR. JOGLAR: That's true for the first row
5 there.
6 MR. BANERJEE: Which ones are true, which
7 ones?
8 MR. JOGLAR: The first row, it was cables
9 burning after they were ignited. The other ones are
10 the actual fuel that you see. So it's actually
11 cables.
12 MR. HAMINS: There were actually cables in
13 B#3, and I believe in B#5. However, their
14 contribution to the heat release rate happened at very
15 late times in the experiment. We did not use that
16 portion of the data for the validation. The principal
17 fuels as listed I believe are correct, and they vary
18 in the type of hydro carbonates being burned. For
19 example, ethanol is a lightly-sitting fuel whereas
20 acetylene is a heavily-sitting fuel. This has impact
21 on radiative heat transfer.
22 We tried to cover a parameter range that
23 encompassed a broad range of fuel types. And you can
24 see on the heat release rate, there was about a factor
25 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

1 immediately, so I'm showing it now. So experimental
2 heat release rate drives fire affects, and it's
3 uncertainty dominates model sensitivity. So we focus
4 our attention in the experiments on the heat release
5 rate and on the uncertainty associated with it. There
6 are two ways that it's measured as I've shown here.
7 And you can see from the FM data, for example, that
8 there is some variation. The measurement has some
9 uncertainty. Okay. Let's look at the next.
10 MR. APOSTOLAKIS: Before you go from that
11 slide, you said that M dot is measured and KI_A is
12 estimated. What is the typical range of KI_A?
13 MR. HAMINS: Yes. It's fuel-dependent
14 because acetylene, for example, produces copious
15 amounts of soot. In other words, you're not producing
16 CO2 and water vapor. And thermodynamically, you're
17 not producing complete combustion, so it's a reduced
18 amount. It's a factor then of how complete the
19 combustion is. It varies. For heptane, for example,
20 it's on the order of 85 percent approximately. So for
21 other fuels like acetylene, depending on the scale,
22 depending on the ventilation conditions, it can be 50
23 percent. So we've looked at each of these experiments
24 and tried to estimate what the value of the combustion
25 efficiency is and what its uncertainty is. That was

1 the job that we did in Volume II.

2 MR. APOSTOLAKIS: So this is the input

3 uncertainty, right?

4 MR. HAMINS: This is the uncertainty in

5 the experimental measurements. The key input

6 parameter -- we find the most sensitive parameter in

7 all of the models is the heat release rate.

8 MR. APOSTOLAKIS: Right.

9 MR. HAMINS: Yes.

10 MR. APOSTOLAKIS: That's what we just

11 discussed.

12 MR. HAMINS: Yes.

13 MR. APOSTOLAKIS: So that's an input

14 uncertainty?

15 MR. HAMINS: That's correct. For the

16 models, it's an input uncertainty, yes.

17 MR. APOSTOLAKIS: Now you're talking about

18 experimental uncertainty?

19 MR. HAMINS: Yes. And we lump both what

20 we call model sensitivity to input parameters which

21 are experimentally based and experimental

22 measurements. We lump them all together as

23 experimental uncertainty. And I'll try to describe

24 that concept in a moment. So many of the test

25 reports, unfortunately, do not provide uncertainties

1 for the individual measurements. Some do, but where
2 that was not true, estimates were based on previous
3 experiments at NIST using similar instrumentation.
4 Measurement uncertainty itself depends on the exact
5 type of the instrumentation, the experimental
6 procedure and the details of the measurement scenario.
7 I'd like to talk first about BE#3 which
8 was performed at NIST in 2003. This was a project
9 funded jointly by NRC and NIST. It was part of the
10 ICFMP series of projects. You can see the heptane
11 spray fire burning in the background. This was a
12 large compartment, 22 meters long, 7 meters wide, 4
13 meters tall. It was the most comprehensive set of
14 measurements conducted at NIST/NBS. There were 10 to
15 7 data points taken, 350 measurements -- instruments
16 were used per test. We measured the heat release rate
17 using oxygen consumption calorimetry. We measured the
18 fuel flow to assure that it was consistent with that
19 result. We did another consistency check by looking
20 at the energy balance. Where did the energy go, out
21 the door, through the walls, energy enthalpy going to
22 heat up the compartment gases? So through these
23 consistency checks, we felt that we were getting a
24 pretty good handle on the uncertainty.
25 MR. BANERJEE: What's the spray as opposed

1 to a pool fire?

2 MR. HAMINS: Yes. A spray fire is simply

3 fuel emanating from a nozzle that is impinging onto a

4 flat plate. It's a very nice way to control the rate

5 of delivery of a fuel, and we've been using it

6 extensively at NIST. We were able to provide 400 to

7 2300 kilowatts through these spray fires. We were

8 looking at the thermal environment in these

9 compartments. And they were instrumented with cables.

10 We were looking at heat flux to targets. We were

11 looking at heat flux to the wall. We were looking at

12 the gas space temperatures at seven horizontal

13 locations to try to understand the vertical

14 temperature gradient inside this very large

15 compartment.

16 Experiments were conducted with open and

17 closed door and with mechanical ventilation. There

18 was a mechanical supply duct and exhaust duct on

19 opposite sides of the compartment. The detailed flow

20 through the ducts was measured using PITOT tubes and

21 what's called bidirectional probes. Our intent was to

22 document all the boundary conditions and initial

23 conditions. We measured thermophysical properties of

24 surface materials and their optical properties. We

25 need to know the imocivity of the surface materials.

1 Those were measured at NIST. We tried to nail down
2 the boundary conditions for validation effort.
3 I'd like to go on now and discuss briefly
4 some of the other experiments. I conducted the --
5 MR. BONACA: These experiments, I mean you
6 have a -- you do not address fire propagation, I
7 guess?
8 MR. HAMINS: That's right. We are not
9 testing the models for fire propagation. We're
10 looking at steady burning.
11 MR. APOSTOLAKIS: None of the experiments
12 did that?
13 MR. HAMINS: That's correct.
14 MR. BONACA: Does it mean switchgear room
15 you have all these cabinets --
16 MR. HAMINS: Of course.
17 MR. BONACA: -- you will have propagation?
18 MR. HAMINS: And there was a fire in an
19 electrical cabinet, as Bijan mentioned, in this
20 particular set of experiments. However, I believe, if
21 I'm not mistaken, the cabinets were empty, and there
22 was no contribution to the heat release rate during
23 the period of time which we were interested in looking
24 at model validation.
25 So this was a one meter propylene gas

1 burner in the middle of the room. Again, this is a
2 big room, 18 meters by 12. As I was saying -- just
3 let me mention one more thing, I was the PI on B E
4 number 3. We spoke to the PIs on all of the
5 experiments in order to really try to understand and
6 make sure we understood the instrumentation that was
7 used, to make sure if there were any questions about
8 the documentation and the reporting in order to really
9 be able to do the best job possible on estimating on
10 measurement uncertainties.
11 The NBS tests were conducted in 1985.
12 Rick Peacock was involved with those. A corridor
13 connected two rooms. A rather small natural gas fire
14 was in the back of one of the rooms, and the thermal
15 environment was measured.
16 MR. BANERJEE: How did you measure -- you
17 did this oxygen calorimetry you said on --
18 MR. HAMINS: Yes.
19 MR. BANERJEE: -- the other ones? What
20 sort of methodologies were used to estimate the heat
21 release rates?
22 MR. HAMINS: Yes. Mass loss was measured
23 by placing a load cell, which is essentially a strain
24 gauge that's water cooled to avoid thermal affects.
25 Underneath, a pan of fuel. And as the fuel

1 evaporates, the mass loss gauge instrument gives a
2 voltage reading which is calibrated. So we're able to
3 follow as a function of time the mass loss. Then
4 through assumption of the combustion efficiency and
5 understanding the heat of combustion, idealized heat
6 of combustion, we're able to estimate the heat release
7 rate for that fire.
8 MR. BANERJEE: How did you make an
9 estimate of the combustion efficiency?
10 MR. HAMINS: Yes. The combustion
11 efficiency is not well understood for visciated
12 compartment fires. It's not understood for all fuels.
13 The scientific literature was consulted. New
14 experiments at NIST are looking at combustion
15 efficiency, and we have some good information on that
16 from those experiments. What we're trying to do there
17 is look at the thermodynamics, so we measured the
18 exhaust products, measure all the species, and from
19 that one can calculate thermodynamically what the
20 efficiency of combustion is. That's how we got a
21 handle on --
22 MR. BANERJEE: You sort of postulated
23 certain reaction paths based on the species you saw
24 and looked at --
25 MR. HAMINS: No. We didn't postulate.

1 Just thermodynamically one can calculate based on
2 heats of formation without any kinetics. Just looking
3 thermodynamically, one can estimate what the
4 combustion efficiency was by measuring gas products in
5 the exhaust stream.
6 MR. BANERJEE: And you'd have to measure
7 soot as well, right?
8 MR. HAMINS: Yes. Soot was measured.
9 Sure.
10 MR. KHALIK: Slide number five, I think
11 you skipped over that?
12 MR. HAMINS: That's possible.
13 MR. KHALIK: Slide number five, there.
14 MR. HAMINS: Well, not the one that I
15 have. It says FM Sandia National Lab.
16 MR. DREISBACH: It should be six.
17 MR. HAMINS: This one?
18 MR. KHALIK: Should be six. Maybe six.
19 Okay. Now this is inconsistent with what was said
20 before in that these are 500 kilowatt propylene gas
21 burners. And what was said before was that the
22 propylene was just the initial trigger of the fire.
23 MR. HAMINS: I believe that's not correct.
24 I'll stand by my statement that this was a propylene
25 gas fire.

1 PARTICIPANT: Anthony Hamins is correct.
2 When we made the statement, we were confusing two sets
3 of Sandia experiments. And what is in this is
4 correct. It's actually a propylene fire.
5 MR. KHALIK: Okay.
6 MR. NAJAFI: This test was done as a test
7 to measure the affect of a fire outside of an
8 electrical panel. The example that you set panel to
9 panel fire, so there was an empty panel, fire source,
10 another empty panel, and they measured the temperature
11 on the surface inside the adjacent panel and in the
12 center of the adjacent panel. So that was the idea to
13 --
14 MR. APOSTOLAKIS: But that's a different
15 experiment.
16 MR. NAJAFI: Correct. I want to correct
17 what I said. That was a different set of experiments.
18 MR. KHALIK: So for the record, the
19 statement that you made earlier was incorrect.
20 MR. NAJAFI: That is correct. For the
21 record, that was a different experiment, not this one.
22 It was done also at Sandia and Factory Mutual. That's
23 what confused me. But that's a different experiment.
24 MR. HAMINS: Okay. The next set of
25 experiments were contributed by VTT Finland. These

1 were experiments in a very large turbine hall. This
2 was part of the ICFMP project. The experiments were
3 conducted in 1998, 1999. Twenty meter tall sloped
4 ceiling, 27 meter long. This was the largest volume
5 that was tested. There were four types of
6 measurements conducted here looking at hot gas layer
7 temperature and depth, average flame height and plume
8 temperature. The heat release rate in this experiment
9 was determined form mass loss.
10 MR. BANERJEE: And, again, analysis of the
11 gases?
12 MR. HAMINS: Yes. The next experiment is
13 BE#4. This is from Germany as is BE#5. Here, a one
14 meter square pan of jet fuel in a compartment with
15 concrete walls was tested. It's a very large fire in
16 a small compartment. We're trying to look at a wide
17 parameter range of G* and D*. The heat release rate
18 in this experiment also was determined from mass loss
19 rate. There were some instrument malfunctions and
20 fluctuations later in the test. That part of the data
21 set was not used. We focused on high quality data.
22 MR. BANERJEE: PITOT tubes as well for the
23 velocity field?
24 MR. HAMINS: The velocity field here I
25 don't believe was -- oh, inside the exhaust duct,

1 there was no -- in this experiment, no. Because mass
2 loss was used to determine the heat release rate. In
3 the next experiment in Germany, BE#5, the exhaust had
4 to measure the mass flux through the exhaust in order
5 to determine the heat release rate. But the velocity
6 field inside the compartment was not measured.
7 MR. BANERJEE: But temperatures were?
8 MR. HAMINS: Temperatures were measured,
9 yes.
10 MR. BANERJEE: Vertically and
11 horizontally?
12 MR. HAMINS: Vertically and at three
13 locations vertically I believe. Several locations
14 vertically.
15 MR. KHALIK: So in the experiments where
16 you have a fuel spray, I can see how you can control
17 Q dot to make it constant with time so you get a top
18 hat distribution of Q dot.
19 MR. HAMINS: Yes. Right.
20 MR. KHALIK: But what is the time history
21 of Q dot when you have an experiment of this type.
22 There must be some strong time dependence of Q dot.
23 MR. HAMINS: Yes, there is.
24 MR. KHALIK: And what value would you then
25 use to characterize this?

1 MR. HAMINS: Here are two examples. One,
2 BE#2 on the left, and FM data on the right. So the
3 mass loss data in BE#2 is shown, was determined from
4 the load cell. Then that measurement was converted.
5 And here you see the time-bearing heat release rate.
6 So what I showed in the table was approximately the
7 maximum or peak value for that case.
8 For the FM data in the table, I listed the
9 steady burning value which, on average, was about 450
10 kilowatts as you can see from the plot shown here.
11 I was trying to characterize, give you a
12 feeling for the types of heat release rates that were
13 investigated and used for the comparison to the
14 models.
15 MR. BANERJEE: With the gas burner also
16 you can, I suppose, keep a relatively constant --
17 MR. HAMINS: Absolutely. Yes.
18 MR. BANERJEE: Yes. But it's the, I
19 guess, the load cells, as you said, it's just burning
20 off of must have some variation.
21 MR. HAMINS: Okay. These were the
22 parameters that were predicted by the model.
23 MR. APOSTOLAKIS: Let's stop for a moment
24 here. In the report, you make a very explicit
25 statement about intrinsic uncertainty. You say model

1 intrinsic uncertainty is uncertainty associated with
2 the physical and mathematical assumptions and methods
3 that are an intrinsic part of the model formulation
4 and its implementation. And this uncertainty is not
5 part of the model input uncertainty. The methodology
6 for examining this type of uncertainty is described in
7 Reference 43, which happens to be a thesis from the
8 University of Maryland. And there is no other
9 information provided.
10 Now when I hear, without reading the
11 report, that you are validating models, I sort of
12 expected that you would address what you call
13 intrinsic uncertainty. But you're saying, no, go
14 somewhere else. And I don't even know how -- what
15 Maryland does there and whether it's an accepted way
16 of doing it.
17 MR. HAMINS: There are --
18 MR. APOSTOLAKIS: Isn't that a little
19 strange for a project of this magnitude to dismiss
20 this model intrinsic uncertainty in four lines?
21 MR. HAMINS: May I address your question?
22 MR. APOSTOLAKIS: Of course.
23 MR. HAMINS: And perhaps Kevin would like
24 to chime in. We were going to move towards the
25 sensitivity analysis and how experimental uncertainty

1 was used in this process, in this methodology
2 development. There are certain uncertainties that we
3 are not able to quantify. For example, the
4 approximations to the Navier Stokes equations, how k-
5 epsilon modeling versus LES modeling may be better or
6 worse in some cases. There are a whole slew of
7 approximations used in the model development. We
8 can't get a handle on those mathematical assumptions.
9 What we do, and I'll try to show that in the next few
10 slides, is we have a more stringent uncertainty bound.
11 And by having this more stringent uncertainty bound,
12 we're asking for the model calculations to fall within
13 these uncertainty bounds that are narrow. And it
14 makes the comparison more challenging. So we are
15 fixating on a portion of the uncertainty, not the
16 entire uncertainty which makes the validation even
17 more challenging and difficult. So we agree that
18 there are certain uncertainties that we cannot
19 characterize, and we have to find a resolution. We're
20 moving on with the validation using the methodology
21 that I'll describe. And we would welcome your
22 comments.
23 MR. JOGLAR: But I wold like to add in
24 this Volume II, we are defining what uncertainties we
25 are capturing, and those are reflected in the

1 uncertainty bounds that Anthony is describing. When
2 we plot our results, the comparison between
3 experimental data and models, we see if they fall in
4 or out of these uncertainty bounds which, again, are
5 capturing the uncertainty that we could quantify. And
6 in my personal opinion, that in and of itself suggests
7 where model uncertainty issues should be. Because if
8 you're falling outside of these uncertainty bounds
9 that we can calculate, then it's perhaps because the
10 model is introducing some uncertainty. So our results
11 may suggest model uncertainty issues that we should
12 explore later. That goes to your original comment,
13 but it's not that we are not considering them. It's
14 just we're quantifying the uncertainty that we can.
15 And when we see our results against those, that
16 suggests where there may be other sources of
17 uncertainty such as model uncertainty.
18 MR. APOSTOLAKIS: But the intrinsic
19 uncertainty is there, right? It's there. I mean in
20 the red line you show there, the red curve, it is
21 there.
22 MR. HAMINS: Yes.
23 MR. APOSTOLAKIS: So it does affect the
24 results. And you're saying here: however, a sense of
25 the size of the intrinsic uncertainty of the models

1 can be ascertained from the results of this study, and
2 the question is how?
3 MR. HAMINS: From the difference between
4 the models and the measurement results.
5 MR. APOSTOLAKIS: So then the
6 uncertainties -- I mean the uncertainty in the inputs
7 -- I just don't see --
8 MR. HAMINS: Can I go on and try to
9 explain --
10 MR. DREISBACH: -- move along, and we'll
11 explain more completely --
12 MR. HAMINS: I think the next --
13 MR. DREISBACH: -- your issues.
14 MR. HAMINS: The next two slides will help
15 answer some of your questions.
16 MR. APOSTOLAKIS: But one last question.
17 "The methodology for examining these type of
18 uncertainties is described in reference 43." How did
19 you decide that that methodology was appropriate?
20 MR. DREISBACH: I don't think the
21 statement say anything about appropriateness of that
22 methodology.
23 MR. APOSTOLAKIS: If you say that it is
24 examining as described, it implies that if I want to
25 do something, I can got to Reference 43.

1 MR. JOGLAR: I have tested that
2 methodology.
3 MR. APOSTOLAKIS: You have what?
4 MR. JOGLAR: Tested it. I have tried it
5 using information generated from this project. It's
6 not documented in the project that I did, but my
7 personal experience with it suggests that this data is
8 useful for that method; and that method, it has
9 practical applications for like Fire PRA.
10 PARTICIPANT: But we don't know what the
11 method is, though.
12 MR. JOGLAR: Well, the method basically
13 say I calculate the number using a model. What is the
14 probability that that number is real, it represents
15 the reality.
16 MR. APOSTOLAKIS: That has been the
17 question from day one.
18 MR. JOGLAR: Well, it's another
19 methodology to address that. I mean our exercise that
20 we did at EPRI is documented in a conference paper, so
21 I mean our experience with it is that it's useful, but
22 it's, as you say, another method to address that
23 question.
24 MR. APOSTOLAKIS: Since you used it, then
25 why didn't you put it in the report?

1 MR. NAJAFI: That was not clear. At the
2 initial time that we started this project, it was not
3 within the scope of this project. As it was intended,
4 this was to validate and verify these models. As a
5 user end, this may be a subject for the User's guide
6 project that you will see basically. And there is a
7 project that Jason will describe at the conclusion
8 that we are contemplating to move into a document
9 called the user's guide of this document. How do you
10 use this color coded. That may be a topic to be
11 included there, how do you use it even within a
12 probabilistic framework, which is what it is. How do
13 you get the results of this document and use it, if
14 you wish, within a probabilistic framework and uses
15 that methodology and applies it to this.
16 MR. APOSTOLAKIS: Let's go on.
17 MR. HAMINS: This slide shows a typical
18 experimental result and a model calculation for the
19 temperature. These are actual data that were used in
20 the validation study. So the fire at time zero was
21 turned on. The temperature in the upper gas layer
22 temperature, the average temperature was determined
23 through experiments. It peaked and we denote that
24 peak as E_P. That's the experimental maximum or peak
25 value of the temperature at about 600 secs. Then we

1 turned the fire off, and the temperature decayed. The
2 model predictions are also shown.
3 The question we're trying to answer is how
4 to compare these two curves. So what is a good basis
5 for comparison of these two curves. There have been
6 many studies that compare experiments with models, but
7 they have essentially qualitative in nature. We've
8 tried to develop a quantitative evaluation. This work
9 is similar to a 1997 CFD study, used a similar
10 methodology. It was published in *J. Fluids*
11 *Engineering*.
12 Where experimental is used as a metric, as
13 the basis for comparison between these two curves --
14 and I want to highlight the fact that we compared the
15 peak values. We did not compare the entire curves.
16 We compared the peak values. And let me mention one
17 other thing. ASTM does not give specifics on how the
18 two models and experiments should be compared. They
19 give general guidelines. The methodology developed
20 here is unique for fire science.
21 MR. APOSTOLAKIS: Were the peak values
22 usually at about the same time?
23 MR. HAMINS: Yes. The data was monotonic,
24 and the peak values may have varied a percent or two,
25 but not much more than that. They were very similar.

1 So here I'd like to describe the methodology. So we
2 define a relative difference between the models and
3 measurements, and it's a non-dimensional number,
4 epsilon we call it, normalized by the peak
5 experimental value. And this might be temperature or
6 heat flux or whatever parameter of the 13 parameters
7 we're looking at.
8 We also determine -- well, let me go to
9 the plot again. So I've re-plotted the data. The
10 same plot now is shown with uncertainty bars for both
11 model and experiment. And in this approach that we're
12 using, we're asking the question is there overlap of
13 the uncertainty bars. That's essentially the basis
14 for comparison between models and measurements that
15 we're using. And the derivation of this combined
16 measurement in model uncertainty is in the Volume II.
17 I don't want to go through all the details.
18 MR. KHALIK: But just for clarification,
19 the line that you call model prediction uses the
20 nominal values of the parameters for the experiment?
21 Is that correct?
22 MR. HAMINS: The uncertainty in the
23 models?
24 MR. KHALIK: No. The red line, the solid
25 line in the model prediction uses the nominal values

1 of all parameters.

2 MR. HAMINS: Those were the calculated

3 results from the models --

4 MR. KHALIK: Using?

5 MR. DREISBACH: Using the specified --

6 MR. HAMINS: -- characterization of --

7 MR. DREISBACH: -- nominal values of the

8 independent variables.

9 MR. APOSTOLAKIS: And the red uncertainty

10 on the left is due to what?

11 MR. HAMINS: Yes. It's sensitivity to

12 uncertainty and input parameters such as heat release

13 rate.

14 MR. APOSTOLAKIS: So you said for this

15 particular experiment, we're not really sure what the

16 heat release rate was, but here is a range, and if I

17 put that in the code, I get this?

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

19 --

20 MR. APOSTOLAKIS: It's really a

21 combination of both input uncertainty and model

22 uncertainty, intrinsic uncertainty.

23 MR. HAMINS: Yes.

24 MR. APOSTOLAKIS: Because it's there.

25 MR. HAMINS: Well, the model uncertainty

1 would come out -- any variation of the model
2 uncertainty from reality comes out in the model
3 calculation.
4 MR. APOSTOLAKIS: Yes.
5 MR. HAMINS: And it would be included in
6 the sensitivity to the input also. Yes.
7 MR. BANERJEE: Yes. I suppose you --
8 model uncertainty, let's say you were using something
9 like the epsilon model, so then you have these seven
10 or eight parameters you fool around with, and they
11 actually have some range of variability. and if you
12 put that in, you'd get an uncertainty there based on
13 varying those. But you haven't done that type of an
14 uncertainty analysis. You're just fixing it at
15 whatever the model parameters are fixed at. Or if
16 you're doing say LES, it would be the Smagorinsky
17 constant. You're just taking some Smagorinsky
18 constant. You're not looking at the sensitivity of
19 the results to the Smagorinsky constant?
20 MR. McGRATTAN: Not in this analysis, no.
21 MR. BANERJEE: Right.
22 MR. McGRATTAN: I mean we do that off
23 line, but not here.
24 MR. KHALIK: So how are the error bars
25 then determined around this red line?

1 MR. HAMINS: The error bars were
2 determined for the model through sensitivity to
3 uncertainty in experimental input parameters.
4 MR. KHALIK: And that was done with box
5 statistics of some sort?
6 MR. HAMINS: I'm going to go through that
7 in a moment. And I'll show you that. And the
8 experimental uncertainty was determined for each
9 particular instrument looking at repeatability and
10 propagation of error for that particular instrument.
11 The plot on the right then is a summary
12 for CFAST for the temperature results for all 26
13 experiments for both temperature and hot gas layer
14 depth. And these sorts of plots -- you'll see it in
15 the modeling section -- the idea here was to get to
16 the combined uncertainty provides a value for which we
17 can compare to the relative difference, this epsilon.
18 And you'll see these lines on these types of plots.
19 And the and the question is how well do the
20 experimental data, do the relative differences fall
21 within these variants of epsilon which we call the
22 combined measurement and model uncertainty. So the
23 question is shown on the left side of the screen, is
24 epsilon less than U_c, the variants expanded relative
25 uncertainty of the measurement and models.

1 MR. APOSTOLAKIS: U_c then is a standard
2 deviation?
3 MR. HAMINS: Yes. It's the expanded
4 standard deviation. It's a standard deviation two
5 times the standard deviation, so 95 percent confidence
6 internal. Okay?
7 MR. APOSTOLAKIS: U_M squared is the
8 variance of the model uncertainty?
9 MR. HAMINS: Yes.
10 MR. APOSTOLAKIS: And the other one is an
11 experimental uncertainty?
12 MR. HAMINS: Yes.
13 MR. APOSTOLAKIS: So if I take the square
14 root of the sum of the squares, I get the variance?
15 MR. HAMINS: Yes.
16 MR. APOSTOLAKIS: I mean the standard
17 deviation.
18 MR. HAMINS: Yes.
19 MR. APOSTOLAKIS: What did you say about
20 two times?
21 MR. HAMINS: Well, I'm saying it's the
22 capital U in all three cases are expanded. They are
23 not standard deviation. They are used with a factor
24 of such that the confidence on a Gaussian-type
25 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.

1 And this was done for all the parameters.
2 That's shown in this table. There is a power
3 dependence with Q, that is the heat release rate, to
4 all the 13 quantities on the left side of this table.
5 There are other parameters that become important also,
6 such as in heat flux the radiative fraction. Other
7 things that come into play are the height of the
8 doorway for example and the hot gas layer depth and
9 the soot, for example, the soot yield and the smoke
10 concentration.
11 So the power dependence was typically two-
12 thirds, but it varied from parameter to parameter.
13 Now I'd like to talk about the
14 experimental uncertainty and again use the example of
15 the hot gas layer temperature, the average temperature
16 in the hot gas layer. In the experiments I've
17 described, in almost all of them, gas phase
18 temperatures were typically measured bare-bead
19 thermocouples or aspirated thermocouples.
20 MR. BANERJEE: I just want to clarify. I
21 can see how you did that sort of model uncertainty for
22 the two layer-type models. How did you do that for
23 the FDS-type model?
24 MR. HAMINS: The FDS model provided
25 detailed information locally, and we treated it the

1 same way by using a standard reduction technique to
2 determine the average upper layer temperature and
3 lower layer temperature and depth.
4 MR. BANERJEE: And then you just phased it
5 into this?
6 MR. HAMINS: Yes.
7 MR. BANERJEE: All right.
8 MR. HAMINS: So here again is the hot gas
9 layer discussion for the experiments. Experimental
10 data is shown on the left, and then using this
11 reduction technique, we take that data and determine
12 the average upper layer temperature and lower layer
13 temperature as well as the layer depth, the hot gas
14 layer temperature and depth, use this two layer
15 reduction method. And then propagation of error
16 analysis considered the form of those equations as
17 well as the uncertainty of the temperature
18 measurements, the temperature locations and the
19 spacial resolution of the temperature measurements
20 which was very important. There is a certain distance
21 between the thermocouples in the experiments. In some
22 experiments, they were very crude, a couple of meters
23 between each other. So we didn't have information
24 between the thermocouples where the hot layer dept
25 was. So the spacial resolution was an important

1 consideration in all of the uncertainty estimates for
2 the various parameters.
3 MR. KHALIK: Excuse me. Did you translate
4 the uncertainties in the primary variables into
5 uncertainties in the non-dimensional quantities?
6 MR. HAMINS: Yes. Everything was
7 propagated through, if I'm not mistaken. No? Oh, no.
8 They were done in real dimensional quantities and then
9 we non-dimensional quantities.
10 MR. KHALIK: So do we know what the
11 uncertainties in the non-dimensional quantities
12 associated with the various experiments are?
13 MR. HAMINS: You mean the range? For
14 example the Q* and the D*?
15 MR. KHALIK: Right.
16 MR. HAMINS: We can do that. We haven't
17 done it. But one could do that certainly. Because
18 we've listed what the uncertainty is in the heat
19 release rate, one could determine what the uncertainty
20 in the Q*'s are.
21 MR. KHALIK: So all the uncertainty
22 analysis was done using the raw variables?
23 MR. HAMINS: Yes.
24 MR. KHALIK: Okay.
25 MR. HAMINS: So then here is a summary of

1 the uncertainty results where we've combined them,
2 model and experimental uncertainty for each of the six
3 tests, for the hot gas layer depth and temperature.
4 And one can see that there was a variation in the
5 experimental uncertainty, for example, for hot gas
6 layer depth. That varied by a factor of 2, almost--
7 actually a factor of 6. Very little difference in the
8 uncertainty on the model. The combined values are
9 shown in yellow on the left side. On the right side,
10 we look at the hot gas layer temperature
11 uncertainties. There was again variation among the
12 experiments and among the models and uncertainties as
13 large -- combined uncertainties as large as 30 percent
14 on the temperature for one of the tests and as low as
15 12 percent, 10, 11 percent.
16 MR. APOSTOLAKIS: This is for what model?
17 MR. HAMINS: No. This was using the
18 correlations that represent the fire physics, so one
19 would expect,, for example, in the hot gas layer that
20 an uncertainty in heat release rate would lead to an
21 uncertainty in the hot gas layer temperature based on
22 the Quintiere correction, which I showed earlier. And
23 all the models have that physics built into them.
24 MR. APOSTOLAKIS: Oh, okay. So but it
25 refers to that correlation which is used by several

1 models?

2 MR. HAMINS: Yes.

3 MR. APOSTOLAKIS: Not all.

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

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

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

1 that in the future.

2 MR. APOSTOLAKIS: Let me ask a question.

3 Let's go to the previous slide. Again, from the point

4 of view of the user, if I use that correlation to

5 calculate the hot gas layer temperature, and it gives

6 me a number, then this table tells me that the

7 uncertainty about that number is 14 percent up and

8 down -- no, 14 percent total, right?

9 MR. HAMINS: The expanded uncertainty for

10 the measurements and models was 14 percent in this

11 case.

12 MR. APOSTOLAKIS: That means that it can

13 be 14 percent higher and 14 percent lower?

14 MR. HAMINS: Yes. In terms of -- now this

15 is the relative variance.

16 MR. DREISBACH: I think we need a

17 background. The calculation you make as a user, this

18 is not going to give you the uncertainty of that

19 calculation necessarily. This uncertainty is just

20 used as a metric based upon the experiment.

21 MR. APOSTOLAKIS: Yes. But I'm trying to

22 figure out how to use it for the future. So is it

23 associated with this particular correlation but it can

24 be 14 percent up and down?

25 MR. DREISBACH: That was the reason why we

1 stepped back from trying to quantify the inherent
2 model uncertainty, because we have a variety of models
3 and different technique as far as level the of
4 sophistication in those models. We needed an approach
5 that used a different metric by which to characterize
6 the uncertainty.
7 MR. APOSTOLAKIS: Explain to me then what
8 this 14 percent means.
9 MR. HAMINS: This is the variance of
10 epsilon, what we've show in that table. that table
11 include U_c. And U_c is the variance of epsilon. So
12 epsilon is the relative difference between models and
13 experiments. That's normalized by the experimental
14 result. And the U_c which was in that table then is
15 the combined measurement and model uncertainty which
16 is the variance of epsilon.
17 MR. APOSTOLAKIS: Okay. So an epsilon of
18 2.7 tells me that the model over predicts, right? And
19 that there is uncertainty about that prediction which
20 has this variance?
21 MR. DREISBACH: Yes.
22 MR. APOSTOLAKIS: So why can't I use that
23 in my application? I mean I'm trying to use this now
24 and go and do a PRA for my plant. And I'm using this
25 correlation to calculate the hot gas layer

1 temperature.

2 MR. HAMINS: Can I try to answer that?

3 The question is how uncertain was that epsilon

4 determination. There is uncertainty in the models.

5 There is uncertainty in the measurements.

6 MR. APOSTOLAKIS: Right.

7 MR. APOSTOLAKIS: If we're within those

8 uncertainty bounds, then we have, we say, validated

9 the model. The model has predicted within

10 experimental uncertainty the experiments, within

11 experimental uncertainty, within uncertainty of the

12 measurements and the models, it has -- the combined

13 uncertainty. So that's the basis for our comparison

14 is to look at the variance of epsilon and epsilon.

15 MR. APOSTOLAKIS: I understand what you

16 did. Now I'm taking again the user's point of view.

17 I'm using that correlation to calculate the

18 temperature in the hot gas layer in my plant. I have

19 compared the dimensionalized parameters, and I'm

20 within your ranges.

21 MR. JOGLAR: We are saying that that is

22 the best you can do and you phil confident of that.

23 You don't have to do anymore work. That's what the

24 green represents.

25 MR. APOSTOLAKIS: Let me ask again the

1 question. I have my plant, and my parameters fall
2 within the ranges, and I calculate from the
3 correlation a temperature say of 400 degrees. What
4 does this 14 percent mean to me?
5 MR. HAMINS: If refers to a particular set
6 of experiments. This value of U_c that was determined
7 is an average weighted value for the experiments which
8 I've represented. For the user, that's a -- it's like
9 comparing apples and oranges. It's a different
10 situation.
11 MR. APOSTOLAKIS: So I do not have then an
12 estimate of the uncertainty in my calculation.
13 MR. JOGLAR: Well, if you do all the checks
14 with the dimensionalized parameters and you fall
15 within that, what this suggests is if you calculate
16 your hot gas layer, that will be the uncertainty that
17 is associated with it, but that's the best we can
18 quantify given the uncertainty in the experiments.
19 MR. APOSTOLAKIS: I don't get the same
20 answer from Mr. Hamins.
21 MR. HAMINS: No. It's true. We're
22 getting guidance on the variation between the models
23 and measurements from the epsilon. From that value of
24 epsilon, we're seeing what is the goodness or
25 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 --

1 MR. BANERJEE: I think it's clear what U_c
2 is here in your table. If you calculate the hot gas
3 layer temperature, you could say, okay, I am plus or
4 minus what percentage --- it's here -- let's say 14
5 percent. But that's the best we could do given our
6 experiments.
7 MR. HAMINS: Sure. But --
8 MR. BANERJEE: But we don't epsilon yet,
9 right?
10 MR. APOSTOLAKIS: No. I don't know
11 epsilon. And the other thing I don't know -- I mean
12 why are you saying -- I mean you are implying that the
13 estimate of the code is the best estimate, and you
14 have uncertainty about it. And if the code has
15 intrinsic uncertainty, systematically over estimates
16 or under estimates, that's not true.
17 MR. HAMINS: Oh, no, that's --
18 MR. BANERJEE: In a way -- the way I look
19 at it is that we have collected in these uncertainty
20 bounds inputs to the model like the heat release rate,
21 that uncertainty. We have collected uncertainties
22 from the instruments, and we have developed this range
23 in which we then plot. So if we are outside of there,
24 there are other contributors to uncertainty. Like,
25 for example, so maybe a physical issue with the model,

1 I mean of the physics. And that is not in those
2 lines. And that's what I was suggesting before, that
3 as soon as you start getting far out of these lines,
4 then there are --
5 MR. APOSTOLAKIS: Again. Let's -- you are
6 really focused on what you have done, and I'm taking
7 the point of view of the user now. I'm going to do a
8 PRA, a Fire PRA, go to my room, okay, the cable
9 spreading room or whatever. I calculate the
10 dimensionalized parameters you gave me, and I'm within
11 the ranges. So I'm happy. I run the code or the
12 correlation through the Excel sheet, and I get 400
13 degrees. Now, I have to make a statement about how
14 confident I am that the 400 degrees is in fact 400,
15 and I'm trying to figure out how I can use your
16 results here to make a statement regarding my
17 confidence in the 400 degree estimate.
18 One answer I got is that it's 14 percent
19 up or down with 90-some percent confidence. And my
20 answer to that is that can't be true because it
21 assumes that the 400 degrees, the best estimate is a
22 central value, and uncertainty is up and down, and it
23 could be systematically over or under estimating the
24 result.
25 So, again, what am to do. I don't know

1 epsilon. Do I know epsilon? Do you give me an
2 epsilon here? In other words, if you tell me that
3 epsilon is always 2, then I know I'm always over
4 predicting. But then I still have a problem with the
5 up and down.
6 MR. JOGLAR: I guess that's the issue if
7 you go back to the epsilon U_c. This is giving you U_c,
8 right?
9 MR. APOSTOLAKIS: Right.
10 MR. JOGLAR: Let me see -- is your
11 question.
12 MR. BANERJEE: We don't understand what
13 epsilon is.
14 MR. APOSTOLAKIS: Epsilon is, I guess, the
15 --
16 MR. BANERJEE: Yes. We know what it is
17 there, but how is that being delivered?
18 MR. APOSTOLAKIS: Right. And how does it
19 apply to my calculation when I do it in the future?
20 MR. JOGLAR: Okay. How it applies, it's
21 based on the dimensionalized parameters
22 MR. APOSTOLAKIS: I admit that. I
23 satisfied those requirements.
24 MR. JOGLAR: So I guess what I'm trying to
25 suggest is much simpler -- if I understand correctly

1 your question that if you meet the dimensionalized
2 parameters, and the answer that you get is -- and we
3 have classified, given this analysis, the model
4 capability as, for example, green -- that's the end of
5 the process. You did the best you can, and the
6 validation supports that calculation.
7 MR. APOSTOLAKIS: Take out the 400 degree
8 temperature. How confident am I in that? Can I get
9 an answer to that?
10 MR. JOGLAR: If we classified it as green,
11 the team thinks that you should be very confident.
12 MR. BANERJEE: I guess he's saying that
13 epsilon is less U_c if it is green? Is that why you
14 are really saying?
15 MR. JOGLAR: Yes.
16 MR. HAMINS: Yes.
17 MR. DREISBACH: Yes.
18 MR. BANERJEE: All right.
19 MR. APOSTOLAKIS: You're saying that
20 epsilon --
21 MR. DREISBACH: The characterization of
22 the model's predictive capability is simple there.
23 MR. APOSTOLAKIS: Well, but that's a major
24 observation. My goodness.
25 MR. DREISBACH: We have to deduce this.

1 It's not said anything yet.

2 MR. APOSTOLAKIS: Say that again? I have

3 this 14 percent.

4 MR. DREISBACH: If you make the prediction

5 from CFAST --

6 MR. APOSTOLAKIS: And it's green. I use

7 a green code.

8 MR. DREISBACH: Regardless of what model

9 you use, you find that your model is green and you're

10 within the range that we say you're within, but

11 predictive capability is green, you don't need to

12 worry about any of the other numbers.

13 MR. BANERJEE: But does green mean that

14 epsilon is less than your U_c.

15 MR. DREISBACH: Yes.

16 MR. BARANOWSKY: Lets not say it's

17 absolute, because their clearly is engineering

18 judgment in this. But the answer is, y es, it's very

19 close.

20 MR. APOSTOLAKIS: So the 14 percent is

21 something that I will not use?

22 MR. DREISBACH: Correct.

23 MR. APOSTOLAKIS: All I use is the green?

24 MR. DREISBACH: Correct.

25 MR. APOSTOLAKIS: So I can come to the NRR

1 people here and say I am 95 percent confident that the
2 400 degrees is in fact 400 degrees?
3 MR. JOGLAR: Yes. The colors represent
4 the best judgment of this team based on these
5 analyses.
6 MR. APOSTOLAKIS: No, no.
7 MR. DREISBACH: No. That's not what he's
8 saying.
9 MR. APOSTOLAKIS: No. He said, no. The
10 14 percent was used to declare it green?
11 MR. DREISBACH: Yes.
12 MR. APOSTOLAKIS: But then it's not for me
13 to use?
14 MR. BANERJEE: well, I would have thought
15 the logic -- maybe I'm understanding this wrong -- the
16 logic is that if it is green, then the systematic
17 error that you might have between what you call
18 epsilon there lies within U_c? If it is yellow, maybe
19 it lies outside. So U_c then bounds the error
20 possibly, right?
21 MR. APOSTOLAKIS: But that is still an
22 error.
23 MR. DREISBACH: Yes.
24 (Chorus of Yeses)
25 MR. HYSLOP: This is not really any

1 different than what we do in thermohydraulics when
2 we're looking at ECCS. What they're saying is they
3 have a measure of whether the computer code prediction
4 has a goodness of fit that's acceptable within this
5 range called U_c, not with the uncertainties on it.
6 And we have the same thing if we're computer peak
7 cloud temperature for instance during a loss of
8 coolant accident. We've computed peak cloud
9 temperature, and based on running through similar
10 activities, we only come up with a single estimate of
11 what the temperature is. And we don't look at what
12 the variation or variants on that temperature is and
13 factor that into some risk calculation. And they're
14 not proposing to do the same thing here.
15 What they're saying is this represents a
16 good calculation within the uncertainty that we can
17 resolve to the best of our ability for the
18 experimental and modeling that they've looked at.
19 MR. KHALIK: It still has uncertainty.
20 MR. BANERJEE: But what is implied, what
21 they're not saying is that you also have an estimate
22 of this U_c which is the expanded variability.
23 MR. HYSLOP: Yes.
24 MR. BANERJEE: So really you have that.
25 MR. HYSLOP: And you could expand your

1 analysis to account to the uncertainty in that
2 estimate and propagate it through the risk model if
3 you wanted to do, which is in essence what they did in
4 NUREG-1150 for the containment parameters. They
5 didn't only come up with their best estimate of the
6 parameters. The came up with the ranges and then they
7 picked distributions, which you also could apply here,
8 so that if you predict a peak temperature of 400
9 degrees using this, say, green V&V'd model, you might
10 also have a 50,, 60 or even 100 degree potential error
11 in that with a certain likelihood.
12 MR. APOSTOLAKIS: Which does not flow from
13 this.
14 MR. HYSLOP: Which you could get form this
15 but is not what they're purpose is.
16 MR. APOSTOLAKIS: I'm not sure you could.
17 MR. KHALIK: What is being plotted here on
18 the right.
19 MR. APOSTOLAKIS: All this is telling me
20 is that if I meet all these conditions, I am using a
21 code that has performed well in the past.
22 MR. HYSLOP: Yes.
23 MR. APOSTOLAKIS: It is not telling me how
24 uncertain I am about the predication of code?
25 MR. HYSLOP: Well, it does in part,

1 because you understand through the U_c how uncertain
2 you are in the predication. And you would have to go
3 into the details to see what that is.
4 MR. APOSTOLAKIS: The 14 percent I was
5 told is not a measure of how uncertain I am in the
6 prediction of the code.
7 MR. KHALIK: What is being plotted here on
8 the right is the value of epsilon, is that correct?
9 MR. HYSLOP: That's correct.
10 MR. KHALIK: For each individual
11 experiment.
12 MR. HYSLOP: That's correct.
13 MR. KHALIK: And the line that says 13
14 percent is what you estimated U_c to be, right?
15 MR. HYSLOP: Yes.
16 MR. KHALIK: So if I look at this graph,
17 I say well, roughly half the experiments were less
18 than U_c and the other half had uncertainty for a
19 relative difference greater than U_c. So I'm not sure
20 where you get the 95 percent confidence level
21 associated with that number that you have in the table
22 at the end.
23 MR. PEACOCK: This particular one, I
24 think, is somewhat a special case. If at the end one
25 of the things we particularly say for both zone models

1 is that for the hot gas layer temperature, the
2 calculation is acceptably green, to use a strange
3 phrase, for where the fire is. But the ones that are
4 outside, particularly the ones that are most outside
5 that 13 percent are ones remote from the fire. That
6 doesn't get a green. That gets a yellow, ,because
7 we've decided that's far enough outside the U_c bounds
8 that we're not comfortable saying it's always going to
9 be good.
10 MR. APOSTOLAKIS: So in this example where
11 epsilon is .27, it's outside the range?
12 re; Correct.
13 MR. APOSTOLAKIS: Therefore, what? It's
14 a yellow?
15 MR. PEACOCK: Therefore, you need to --
16 MR. APOSTOLAKIS: It's a yellow?
17 MR. PEACOCK: It's a yellow in this case.
18 MR. APOSTOLAKIS: It's a yellow. But for
19 NRC purposes, though, if I look at the curves, it's
20 pretty good, because it's conservative.
21 MR. JOGLAR: That's why we have a yellow
22 plus, for practical applications.
23 MR. PEACOCK: Conservative if you're
24 interested in maximum temperature. If for example I
25 am interested in detector activation, the fact that

1 the model predicts it rising faster implies that it's
2 going to predict the detector goes off faster than it
3 does. So it depends on the application whether it's
4 conservative or not.
5 MR. APOSTOLAKIS: Well, why don't we then,
6 because of the time, ask you to give us a more
7 definitive at a different committee meeting? The
8 question is --
9 MR. DREISBACH: Definitive answer to what
10 question?
11 MR. APOSTOLAKIS: I'm doing an analysis.
12 I get 400 degrees. What can I say about my
13 uncertainty about that from your results.
14 MR. DREISBACH: Okay.
15 MR. APOSTOLAKIS: Okay? That's the
16 purpose of subcommittee meetings, to identify.
17 MR. PEACOCK: That's a very good question.
18 MR. APOSTOLAKIS: Thank you very much,
19 Pat. And on that happy note, I don't know now. Can
20 we afford an hour for lunch? Half an hour? So we'll
21 be back when, at 1:00?
1 (Whereupon, the matter went off the record
2 at 12:21 p.m. for a lunch break, and back on the
3 record at 1:10:04.)
4 MR. APOSTOLAKIS: Okay. We're back in

1 session. Who's next?

2 MR. DREISBACH: We're going to go right to

3 the results, the final presentation.

4 MR. APOSTOLAKIS: Very good.

5 MR. DREISBACH: And then if we have some

6 time left over, we'll go in the model by model --

7 MR. APOSTOLAKIS: Yes. We also have to

8 discuss at the end your presentation to the full

9 committee.

10 MR. DREISBACH: Yes.

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

12 results.

13 MR. DREISBACH: Bijan's going to start out

14 the summary, go through that.

15 MR. APOSTOLAKIS: So which presentation is

16 this?

17 MR. NAJAFI: This is where it says summary

18 results.

19 MR. DREISBACH: The last presentation.

20 MR. APOSTOLAKIS: Okay.

21 MR. BANERJEE: We are not going to hear

22 about FDS? I was looking forward to it?

23 MR. DREISBACH: If we have time. We're

24 trying to get to the crux of our report, and we hope

25 a lot of the questions so far. And then if we have

1 time, we'll go through the individual model results.
2 MR. APOSTOLAKIS: So that's the very last
3 four or four slides?
4 MR. DREISBACH: Yes.
5 MR. APOSTOLAKIS: Okay.
6 MR. DREISBACH: Bijan's going to start it.
7 MR. NAJAFI: Yes. Actually, we're going to
8 go through -- I mean this presentation I've added in
9 the middle of this -- we talked this morning about an
10 example -- I mean at least what is in our mind, or my
11 mind, or collective mind, how the results could be
12 used. I'm sure we talked about that through this
13 sometime during this morning, but I mean I think
14 that's one of the most important things. We need to
15 get a couple of messages in mind in here.
16 One, in my mind, a better understanding of
17 what is the product that we have in front of us. I
18 want to understand whether we like it, whether we
19 think it is done, finished, to the end, or where it
20 should be, or whatever. I think we need to make it
21 clear what it is that we have. And I think there is
22 some confusion. And hopefully, hopefully, I think
23 that's the first step that we have to jump, that we
24 make sure everybody has the same understanding of what
25 we have.

1 The second is that I will attempt, through
2 either an example or a process, show you, at least in
3 my mind, how I fit, how I think that product, as it is
4 today, can meet the need. And maybe not 100 percent,
5 but how it cane serve it's purpose today. Where we go
6 with it a year from now, that's a parallel path. In
7 my mind, we have to decide how we can use the product
8 to support all of our stakeholders with the product we
9 have at hand.
10 Also, I'll start with something maybe very
11 fundamental to show basically what is the process --
12 I mean please be patient -- Some of these may be
13 obvious and self-explanatory, but in my mind, serves
14 purpose -- This is a process that a user will go
15 through. First a user defines a fire modeling
16 objective.
17 And what objective means, what that step
18 means is a user will take a question -- a question is,
19 for example, I have found a hole in my fire door.
20 That's a question. What do I do? So I have -- To
21 define the fire modeling objective, I have to take
22 that question -- or the question may be a PRA -- what
23 is the fire risk associate with the control room in
24 plant x.
25 I have to take that question and translate

1 into a set of fire scenarios or conditions that I can
2 use these fire models to evaluate the conditions. So
3 I take that objective and translate it into I need the
4 upper left corner of the room at the surface of the
5 cable tray x. So that is the purpose of step one.
6 That's the first think you have to do, take the
7 question and decipher it down to a specific measurable
8 thing. That's what we do.
9 MR. APOSTOLAKIS: Bijan, do you envision any
10 questions that are not related to risk?
11 MR. NAJAFI: Yes.
12 MR. APOSTOLAKIS: Like?
13 MR. NAJAFI: Insurance. NEIL does that all
14 the time. In fact, NEIL is developing their own risk-
15 informed package of how to risk-inform an insurance
16 practice.
17 MR. APOSTOLAKIS: Yes. But that's risk-
18 informing it.
19 MR. NAJAFI: Risk-informed, what we call,
20 may be sometimes performance-based is used to
21 determine adequacy of a fire protection feature or
22 system using fire modeling alone. So if --
23 MR. APOSTOLAKIS: In the regulatory arena,
24 would there be any case where --
25 MR. NAJAFI: Without risk?

1 MR. APOSTOLAKIS: -- you do not need risk
2 and use these models?
3 MR. NAJAFI: It depends.
4 MR. APOSTOLAKIS: In Appendix R for example,
5 I don't think there is any room for models like this,
6 is there?
7 MR. NAJAFI: Oh, it could be. It could be.
8 I'll give you an example. If somebody came and said
9 in a lot of those thermo lag days issues that were
10 found that you had to protect -- had no risk, and it
11 was implied that the risk was adequate if you
12 protected the, safe shutdown train of interest in a
13 room. So if you protected it, risk was fine. So if
14 somebody found out that that material, instead of
15 withstanding a three-hour fire can only withstand a
16 two-hour fire now, you could use the fire modeling if
17 you can demonstrate theoretically that a fire exposure
18 that you get from the hazard in the room is equivalent
19 to a three-hour fire in a tested configuration,
20 because that rating comes from a fire test.
21 MR. HYSLOP: So the bottom line, George, is
22 that you can have exemptions to the Regulations that
23 would use fire modeling results to determine whether
24 or not a barrier is challenged or whether the hazards
25 are significant in the room.

1 MR. APOSTOLAKIS: But is it fair to think or
2 to assume that the majority of the cases will involve
3 some sort of risk analysis?
4 MR. HYSLOP: I'm in research, not in NOR,
5 but I'll take a guess at it anyhow. I think with the
6 voluntary rule, NFPA 805 requiring a risk analysis
7 with the agency moving risk, the tools developed, the
8 Fire PRA standard, there's a lot of effort going into
9 Fire PRA. So I would expect a lot of Fire PRA
10 applications using these tools.
11 MR. APOSTOLAKIS: In fact, I recall vaguely
12 that we were told in one of our meetings that the
13 majority of the plants are going towards 805. Is that
14 the correct --
15 MR. HYSLOP: You mean more than half?
16 MR. APOSTOLAKIS: Are planning to, not just
17 --
18 MR. HYSLOP: The last I heard, there were 41
19 plants or units that had submitted a Letter of Intent,
20 and there are some plants that are planning to do a
21 Fire PRA that haven't submitted. They're just going
22 to do a Fire PRA.
23 MR. APOSTOLAKIS: So then a major use of
24 this will be some sort of risk analysis?
25 MR. HYSLOP: That is correct.

1 MR. APOSTOLAKIS: I mean NFPA 805 explicitly
2 says somewhere there that any requests for changes
3 will be submitted to the Regulatory Guide 1174, right?
4 So let's --
5 MR. APOSTOLAKIS: So let's have in mind --
6 I know that it means nothing to you gentlemen from
7 NIST, but for us, it's an extremely important
8 Regulatory Guide, as you guys know. So a user will
9 have those things in mind. Now I agree that there may
10 be other cases or there are other cases where, you
11 know -- okay, let's go on.
12 MR. NAJAFI: Yes. I do put a risk
13 assessment as one application of fire modeling, yes.
14 Maybe the most important one but --
15 MR. APOSTOLAKIS: That's why this is a
16 Reliability on PRA Subcommittee.
17 MR. BONACA: But those models were not
18 originally designed or developed because of PRA,
19 right?
20 MR. APOSTOLAKIS: No.
21 MR. NAJAFI: Some.
22 MR. APOSTOLAKIS: We realized when we
23 developed the methodology for fire risk assessment
24 that we needed this step. And the first thing you do
25 is, of course, what's out there and over the period of

1 years, EPRI developed FIVE. Then we found out that
2 NIST had CFAST. The French, EDF, developed MAGIC.
3 So, you know, the goal was to utilize the expertise of
4 the fire safety people to do a decent job for our
5 purposes. Okay, step two.
6 MR. NAJAFI: Step two. The step two,
7 basically once you have defined what you're objectives
8 are, you have to go into the room and collect or
9 define the right fire scenarios and characterize them.
10 And what I mean specifically, I'll go through an
11 example if we can, the next two slides that I gave
12 you, the examples of those scenarios. What is
13 important to recognize -- there was a lot of talk
14 about the uncertainties and various forms of
15 uncertainties that we in this project, we've tried to
16 sort of dissect the problem of input uncertainty to
17 the extent that we call it the input, for example, the
18 characteristic of the fire source. Understood that
19 when you put the fire source into a fire model, the
20 intensity may change because of oxygen limitations and
21 all that, but the initial characteristics of the fire
22 at its start, at time zero, it needs to be defined.
23 That is the uncertainty that we deal with somewhere
24 else. As part of the characterization of the fire
25 scenario, we deal with that. And right or wrong,

1 there are methods to do that.

2 So that part of it -- and that relies a lot

3 on your objective. If your objective is risk

4 assessment, you may pick a different set of scenarios.

5 If your objective is to determine or establish the

6 adequacy of a fire door or your suppression system,

7 you may pick different fire scenarios. So depending

8 on what you're looking for, you may take one, you may

9 take ten, and you have to take those that engulf or

10 encompass or challenge the objective.

11 So the next step is where you start picking

12 your -- look at what model do I use. That comes out

13 of many things. One of them is what is it that your

14 scenario wants? Does it want a temperature in a room?

15 Does it want a plume temperature? Is it a radiation

16 scenario? Is it a smoke? Is it important, the smoke

17 generation? So those attributes that you defined in

18 your fire scenario goes into selecting what model you

19 should pick.

20 So that's the first step that you come into

21 our document. At that point, you start looking at our

22 document and say, I'm going to look at that picture

23 that is at the end to see what is the capabilities of

24 these models, not how these capabilities -- a

25 combination of what model can do what and what model

1 can do what thing better or not better. So that, as
2 a first iteration, that's the first time you jump into
3 our document. It says let me pick -- for example, if
4 I am using the plume.
5 MR. APOSTOLAKIS: Do we have this?
6 MR. DREISBACH: No. This is something
7 that's just been created.
8 MR. NAJAFI: I just created it as you were
9 talking about it over there. I picked out --
10 MR. APOSTOLAKIS: But you will give it to --
11 MR. DREISBACH: We can, yes.
12 MR. NAJAFI: Yes. This one basically gives
13 you an example, and I'll go through it. This is
14 basically a switchgear room of a typical nuclear -- of
15 a power plant. This is a problem we designed for one
16 of the training courses. This is a room that is a
17 Division A room. This is the Division B tray, and
18 it's wrapped in a protective device, a thermal
19 barrier. The target that is in this tray, if it's
20 damaged, the only way to get out of the scenario or
21 system requires a manual action. A manual action
22 needs to be taken here. So the issue here is, do I
23 have enough protection? So do I have a fire that can
24 threaten this or not?
25 MR. APOSTOLAKIS: Bijan, maybe you can use

1 a cursor so you can speak to the microphone? The
2 cursor to point on the screen.
3 MR. NAJAFI: So I mean tell me if I'm
4 dragging this too long -- short on time.
5 MR. APOSTOLAKIS: No, you're fine.
6 MR. NAJAFI: Basically, what we're trying to
7 say is do I have any fires that can threaten this one,
8 and at the same time can generate enough smoke that I
9 cannot take a manual action here. So there's a, let's
10 say, two problem. I'll pick the first one. The issue
11 is a three-hour rated barrier, ERFBS means Electrical
12 Raceway Fire Barrier System, has been determined to
13 provide only half an hour of protection. Is it
14 enough? That's the question. That's our issue.
15 General objective: Is half an hour fire rating
16 adequate for this hazard in this room. Fire modeling
17 objective: Estimate surface temperature of the cable
18 inside the cable tray.
19 MR. NAJAFI: So now I go into the next one.
20 This is how we see it. My fire modeling objective is
21 to estimate a temperature. The ERFBS is in the fire
22 plume, so that's the scenario. I went and looked at
23 the scenario, and scenarios in the room says it's a
24 fire that is sitting right in the plume of a
25 switchgear. I know from somewhere else, the NUREG

1 6850, I have some documented place that it says for a
2 switchgear, this is a heat release rate I should use.
3 Outside for a minute, let's assume that this is not a
4 high energy arcing fault. I mean I don't want to make
5 the problem too big.
6 MR. BANERJEE: what is HEAF?
7 MR. NAJAFI: High energy arcing fault.
8 Treat that as a thermal fire, not a boom. It's not a
9 bang. It's just a thermal fire for the moment. So
10 there it tells me use a 500 kilowatt fire because
11 switchgears looks like this, and look like this, and
12 we've done tests and that and that, so it's a 500
13 kilowatt fire with that distribution, plus or minus x
14 percent. So first I come from Table 3-1, which is the
15 color-coded stuff. In that color-coded stuff, it's
16 telling me that I can use basically -- I don't have it
17 here -- but if you look at that color-coded in your
18 handout, there is one that it shows, a green, and one
19 that is shows a yellow plus. So I could use one of
20 those. Okay?
21 So user first selects the first Five-Rev-1.
22 This is where I'm getting a little bit to what this
23 product is and what it's not.
24 MR. BANERJEE: Has the non-dimensional
25 groups entered here?

1 MR. NAJAFI: Good question. I missed that
2 point. I'll add it here. Good question. Basically,
3 that's when you put it together in a hurry. But first
4 user selects basically, let's say, Five-Rev-1, because
5 that gives me a yellow plus, and I know that I can
6 accept some level of conservatism. I go into the
7 dimensionalized group, enter my scenarios, which is
8 the volume of that room, the size of 500 kilowatt, and
9 all of that.
10 First, I determine do I pass the funnel. If
11 I don't, what that tells me -- that -- because
12 remember I said we have three pieces that we have to
13 make fit, experiment, model, reality. If I don' pass
14 the first funnel, our experiment and the reality don't
15 fit. For example, I want a small room, and all I have
16 tested are gigantic rooms, and that makes a
17 difference. That's what would make the claim on the
18 dimensionalized group, that if you don't fit, sorry,
19 my experiment is too far away, too from your scenario.
20 So on experimental uncertainty go through that and you
21 pass, then you use Rev-1. The user selects Rev-1 and
22 obtains, after the dimensionalized groups, obtains a
23 plume temperature of 600 degrees, let's say, okay,
24 which is a 100 degrees below the target damage
25 criteria with a distribution, again, in one of the

1 Appendices of 6850.

2 MR. APOSTOLAKIS: No. Here you don't need

3 a distribution, because you are claiming the 600

4 degrees is a conservative estimate.

5 MR. NAJAFI: Okay. That's exactly. Then I

6 say there's no damage, and that's all I can say. I

7 say no damage because I was yellow plus and I passed

8 the first funnel. No damage. Now, if Five-Rev-1

9 estimates plume temperature of 850, let's say. I did

10 Five-Rev-1 estimates vdid a plume temperature of 850.

11 I can assume a damage. Damages have occurred. Or use

12 MAGIC. Okay? Because that give me a green. What is

13 says is that I think our five for that is too wide,

14 but we think it's on the conservative side. We could

15 make that conclusion based on our numerics in the

16 Appendices. Our MAGIC came within that experimental

17 uncertainty. So we said that it's green, as good as

18 it gets.

19 MR. APOSTOLAKIS: I like the way it sounds.

20 Our MAGIC came within --

21 MR. NAJAFI: As good as it gets.

22 MR. BANERJEE: Keep on sharpening your

23 pencil until you get the answer you want.

24 MR. APOSTOLAKIS: Then there were will be

25 another code miracle.

1 MR. NAJAFI: The thing is that there are
2 models that do better than --
3 MR. APOSTOLAKIS: I understand your point.
4 So the message here, the way I see it, is that I, as
5 a user, will never use epsilon and your U_c and all
6 that. All that was used to declare the code yellow
7 plus or green. As far as I'm concerned, this is not
8 information that I can use. I am using it when I use
9 the color?
10 MR. NAJAFI: You're correct in the sense
11 that I go back to what I said this morning. That's
12 why I call this a pseudo quantitative method. We
13 built this from bottom up in a quantitative sense.
14 But we put a qualitative layer for the end user at the
15 top. Our layer at the top is not quantitative.
16 MR. APOSTOLAKIS: Right. Now, regarding
17 Five-Rev-1, I understand. It's yellow plus --
18 MR. NAJAFI: Take model x model y. I could
19 have put them --
20 MR. APOSTOLAKIS: But when it comes to
21 MAGIC, though, and I get a plume temperature of 650
22 degrees, because it's a more realistic code, right --
23 you declared it green as opposed to yellow plus --
24 don't I really worry about the uncertainty now?
25 PARTICIPANT: It's best estimate plus

1 uncertainty.

2 MR. APOSTOLAKIS: Plus uncertainty. And

3 that's the part where you are not helping right now

4 with everything.

5 MR. NAJAFI: No. I know. That's why my

6 point was -- that's what I said during lunch to these

7 guys. I think we need to present what this product

8 is. We're not claiming this product is a lot of

9 things, and we don't need to claim that it's

10 everything.

11 MR. BANERJEE: MAGIC gives you let's say

12 something like a best estimate of FDS, correct --

13 MR. NAJAFI: MAGIC --

14 MR. BANERJEE: -- terms that we understand.

15 MR. NAJAFI: MAGIC gives us the results that

16 it's within our experimental uncertainty.

17 MR. BANERJEE: When it's green.

18 MR. NAJAFI: Yes. When it's green.

19 MR. BANERJEE: It gives you something which

20 we understand is a best estimate, right?

21 MR. NAJAFI: That is correct.

22 MR. BANERJEE: Now normally, when we come to

23 sort of decisions about this, it's best estimate plus

24 uncertainty.

25 MR. NAJAFI: You're absolute--

1 MR. BANERJEE: Where is that uncertainty.

2 MR. NAJAFI: It's not here. That's why I
3 tried to say -- I mean I'm not trying to oversell
4 this. That uncertainty, when we present the green,
5 we're presenting the green as what it is, which is
6 that best estimate. We do not --

7 MR. BANERJEE: But how do you come up with
8 650 and your limit is 700? What are we to do with
9 this?

10 MR. NAJAFI: When we get to that point, I
11 would say we are -- with those limited set, we are
12 probably at the same situation we were with the IPEEE.
13 We will try to be prudent if that is close enough. I
14 know there's judgment involved. There's no question
15 about it. In the past when we used it, when we got
16 690, 680, we basically said, assume damage. If we got
17 600 -- I know there's subjectiveness involved -- we do
18 not present a systematic model or methodology of how
19 to deal with that in this product. We don't.

20 MR. BANERJEE: But let's say instead of
21 temperature we have something to do with pressure, we
22 saw that your uncertainties on pressure are very
23 large. I mean you had different uncertainties on
24 different parameters. So as long as it was
25 temperature, maybe the uncertainty was 15 percent, but

1 when it was pressure, it was 40 percent. So how do I
2 use my engineering judgment at this point? I have no
3 idea if I'm a user that U_c is 40 percent in one case,
4 15 percent in the other case. I'm just taking the
5 green and hoping for the best, right?
6 MR. NAJAFI: You're correct. But at the
7 same time, that's why those documents, those
8 experimental uncertainties are included in the body of
9 the report so that a user knows that even if you're
10 using a green, because there is still a large
11 experimental uncertainty versus a green, which is
12 within a very small experimental uncertainty --
13 MR. BANERJEE: But green, it could still be
14 green --
15 MR. NAJAFI: With a large experimental
16 uncertainty. Yes, I understand. I think --
17 MR. BANERJEE: But epsilon could be less
18 than your U_c, so in rough terms, it could still be
19 green?
20 MR. NAJAFI: Yes. And --
21 MR. BANERJEE: But I don't know what the
22 number I get means now. Imagine that I had a pressure
23 calculation and I need it to be below 1-1/2
24 atmospheres, and this came in at 1.2 atmospheres.
25 MR. NAJAFI: Let me try to add something.

1 It may help somewhat. I know that there is, even
2 within the green, you pick on the pressure. There is
3 -- I mean I don't know if --
4 MR. BANERJEE: Pick on anything. I mean it
5 doesn't matter. As long as we know --
6 MR. NAJAFI: No. What I want to add here is
7 that there is some hierarchy or priority or level of
8 use, let's put it this way, to these attributes. The
9 good news is that most of the attributes that are
10 commonly used in most nuclear power plant fire
11 scenarios, the answers are -- basically these colors
12 are more useful. Those are plume temperature in many
13 rooms, because a lot of rooms that are -- and if you
14 look at plume temperature -- in fact, you can look at
15 the hand calculations, and if you can live with the
16 conservatism, they do a, I mean, at least an adequate
17 job.
18 MR. BANERJEE: May I suggest something. If
19 you go back to the slide where you were giving us the
20 steps, there should be -- just as you were saying here
21 that you should add examination of the range of
22 parameters --
23 MR. NAJAFI: Yes. That step is missing.
24 MR. BANERJEE: Yes. You might want to also
25 say that people should look at U_c for their various

1 parameters for the point they are, so they at least
2 get some guidance as to how accurate the model is for
3 whatever you're predicting.
4 MR. APOSTOLAKIS: Apparently, though, we
5 have differing opinions as to your organization of
6 that, not among ourselves but also I sensed the
7 previous, Mr. Hamins, that he was reluctant to say use
8 the 14 percent as an indication of uncertainty.
9 MR. NAJAFI: Yes. That's why --
10 MR. APOSTOLAKIS: I really believe you guys
11 should address this question at the full committee
12 meeting, because it's an important question. You
13 don't have to respond, you know, here.
14 MR. NAJAFI: But I'm trying to understand
15 what the question is.
16 MR. APOSTOLAKIS: The question is, I use a
17 green. I get 600 degrees. I have damage at 650. Now
18 I worry about the uncertainties. I mean it's green,
19 it's good. Yes. But it could be 660, with what
20 probability, right? I'm close to the failure limit
21 now, so I have a best estimate calculation, and I want
22 to know why kind of uncertainty goes with that. But
23 the question is, is your effort answering that? The
24 answer may be no. I mean it doesn't have to.
25 PARTICIPANT: If you know, we should --

1 MR. NAJAFI: I mean I would -- back to my -
2 - rest of the team disagree with me if I am -- take
3 the leap of faith or go on the limb and say the answer
4 is no.
5 MR. APOSTOLAKIS: But you're not?
6 MR. DREISBACH: At least directly --
7 MR. NAJAFI: No. We're not.
8 MR. DREISBACH: At least directly, we do not
9 address it.
10 MR. APOSTOLAKIS: Okay. That's my
11 impression, too.
12 MR. NAJAFI: I mean if any of you --
13 MR. APOSTOLAKIS: The next question I have
14 for you is, is this the end of this collaborative
15 project, or are you -- you mentioned the user's guide.
16 MR. NAJAFI: The user's guide is the plan or
17 the scope. And the goal and objective of it is yet to
18 be defined. It's under planning by the Office of
19 Research and EPRI.
20 MR. APOSTOLAKIS: But there will be a user's
21 guide?
22 MR. NAJAFI: If you ask me, as an individual
23 on the record, I think that is one of the key roles of
24 a user's guide, because EPRI did do a fire modeling
25 guide. And that fire modeling guide -- in fact, the

1 chart that you saw, the steps of the fire modeling is
2 right out of the EPRI's fire modeling guide. What
3 that new guide should do is basically integrate the
4 results of this V&V ad what EPRI did prior to that V&V
5 to create a new user's guide that takes into account
6 how do I interpret the results of fire modeling not
7 that I know the results of this V&V exactly answering
8 your question. How do I do that? And that may be the
9 charter, may be, of that user's guide.
10 MR. APOSTOLAKIS: How about this big NUREG
11 that we reviewed recently. JS, it was 6850, was it?
12 MR. HYSLOP: Yes, that was it.
13 MR. APOSTOLAKIS: I mean wouldn't you refer
14 to that at all? I mean --
15 MR. NAJAFI: There is a question also that
16 we have thought about it, that is what is the
17 interface of these two documents, because the NUREG,
18 EPRI 1011989 basically has a section of a -- has a
19 section on fire modeling, and those fire modeling, it
20 says basically go pick your scenarios, pick your model
21 for fire risk assessment and calculate.
22 MR. APOSTOLAKIS: Okay. So you will give us
23 a more definitive answer next time. You already said
24 no, and I agree with you, but you will have two or
25 three weeks to think about it. And it's perfectly all

1 right to say that this is something that you will do
2 in the future.
3 MR. NAJAFI: So it was my goal coming to
4 this afternoon's meeting to make clear what this
5 product is, and this product is qualitative as it's
6 surface. Does it give a distribution of green or
7 yellow or other? No. As far as I know, it does not.
8 MR. APOSTOLAKIS: It does not.
9 MR. NAJAFI: Should it? We can talk about
10 that.
11 MR. APOSTOLAKIS: The other thing I would
12 like you guys to address -- are you done with this?
13 MR. DREISBACH: With this. Yes, we're done
14 with that. If you understand the color-coding,
15 because I was going to talk through that a little bit
16 more.
17 MR. APOSTOLAKIS: Yes, we do. We do?
18 MR. BANERJEE: In rough terms. As any fine
19 structure in this large scale understanding we have.
20 MR. NAJAFI: And if I have gotten the two
21 messages across that this is what this product is and
22 what it's not, number one. And there is still -- it
23 is very important that within the users of today,
24 there is a place for this product to be used, in my
25 opinion, as a user. Because I've been involved in any

1 of the fire risk assessment and the fire modeling,
2 that I think there is a place, as I mentioned here,
3 for the product as it is today.
4 MR. BANERJEE: I was just going to ask you -
5 - I mean I understand, I think, what the product is,
6 but I am not sure that if I was a user I would know
7 completely how to us it, and if I get say the
8 temperatures out of it, and it's close to the limits,
9 I don't know what close to the limits means here.
10 That's really the issue, because if the limit was as
11 George was saying, 650, and I come in at 600, now it
12 could be that that 50 degrees is a very large
13 difference compared to the uncertainty in my results,
14 or it could be very small, and I don't have a feel for
15 that. That's why I'm very uncertain about the end
16 use. I think this is sort of a step in the right
17 direction, but by itself, this product does not sort
18 of give me, at least me, the information that I would
19 like. If I come in with a number here, whether it's
20 temperature, pressure, smoke concentration, doesn't
21 matter, I'd like to know how wrong I could be so I
22 know how far I am away from the limits.
23 MR. DREISBACH: Well let's, just as an
24 example, this is our chart.
25 MR. BANERJEE: Yes. So I take green.

1 MR. DREISBACH: It's green, yellow, so here
2 is an example of what green versus yellow is. So on
3 the left, we have MAGIC.
4 MR. APOSTOLAKIS: Use the cursor. We don't
5 see your finger.
6 MR. DREISBACH: On the left, MAGIC hot gas
7 layer temperature rise. On the right, CFAST rated the
8 fluctual targets. So what we're plotting is measured
9 temperature rise and predicted temperature rise. So
10 it's obviously at the peaks. That's what Anthony was
11 describing before, and we've got these dotted lines
12 that describe what the uncertainty bands are.
13 MR. BANERJEE: But these are different on
14 different predicted quantities, right?
15 MR. DREISBACH: Yes. That's correct.
16 MR. BANERJEE: So if I understood how, in
17 rough terms, you arrived at green is when your epsilon
18 was less than U_c.
19 MR. DREISBACH: Yes. So that's what you see
20 on the left side.
21 MR. BANERJEE: Okay. Let's take that as a
22 working definition. So in laymen's words, let's say
23 the difference between your experiment and your model
24 predictions were within the uncertainty in bolts.
25 MR. DREISBACH: Yes.

1 MR. BANERJEE: I mean you add it up in some
2 ways.
3 MR. DREISBACH: Yes.
4 MR. BANERJEE: Okay. So that gave you
5 green. If it was outside, it went to yellow. If it
6 was -- okay. Now, I still don't know an answer to my
7 question, whether 600 is okay when my limit is 650 or
8 it's not okay, because if the uncertainty band there
9 was more than 50 degrees or something or more than 20
10 degrees, then I would say if it was, let's say, less
11 than 20 degrees, 600 is fine. If it's more than 50
12 degrees, 600 is not fine. So how do I use the
13 prediction from this? Green gives me confidence about
14 the veracity of the method that it is within the
15 experimental uncertainty, experiment plus model
16 uncertainty. However, now I've got a prediction. I
17 don't know what the uncertainty is on that prediction,
18 and that I need in order to be able to use it. So I
19 see this only as a step on the way. It's not yet.
20 MR. NAJAFI: Well, I mean while it's true
21 that it can be said that this is a step towards that
22 goal, I want to also point out that in our supporting
23 document, in our calculations in the numerics, we
24 point out some of the sources of those uncertainties,
25 even though if we do not quantify it and in the end we

1 don't give you a number, because we don't have that
2 method to calculate an uncertainty at this point. We
3 give you some of the sources of those uncertainties,
4 and if you know the sources of the uncertainties there
5 are currently applications such as SDP that they
6 calculate a number and make a decision in the ROP
7 process -- I'm not speaking for the AHJ -- I mean
8 based on experience -- and those determinations are
9 made based on one estimate with some understanding of
10 uncertainty without necessarily quantifying the
11 uncertainty of whether when I use that model or
12 calculated the temperature under SDP plus or minus 100
13 or 200 degrees. That is currently being used. I mean
14 it's being used.
15 I do understand your point. That's why even
16 thought it's not exactly defined as a practitioner,
17 when we got within maybe some discomfort level of our
18 own, we said, okay, this is a failed, assume it a
19 failed. Because there are so many uncertainties
20 beyond that that you don't want even -- where do you
21 find the cutoff? Yes. It is -- I mean --
22 MR. BANERJEE: So giving an upper bound and
23 a lower bound, perhaps that would be useful.
24 MR. NAJAFI: Well, all I can say for that,
25 we're not there now. Because I can tell you, I was in

1 the same place you are a year ago. But our
2 experiments, our technical bases at this point does
3 not support it. And if we wanted to put that, the
4 choice that, in my opinion -- this is personal opinion
5 we have -- is to design or develop or use an existing
6 methodology that the uncertainty. We tried that. We
7 tried in the paper that Francisco is talking about,
8 and somebody told us, oh, boy, you're starting a Ph.D
9 program.
10 MR. APOSTOLAKIS: Heaven forbid.
11 MR. NAJAFI: Well, to put it exactly,
12 somebody told us, I didn't know SAIC gave PhD's. I
13 said, "We don't."
14 MR. APOSTOLAKIS: I think we have resolved
15 this. Said, do you have a question.
16 MR. KHALIK: Yes. I guess I would like to
17 ask about this unlucky user who doesn't make it
18 through the funnel. And the question is how tight is
19 that funnel compared to the expected ranges of
20 parameters that one is expected to get in hypothetical
21 scenarios?
22 MR. NAJAFI: Okay. I can tell you this in
23 two parts. One, we have not tested that funnel, so we
24 should do and we will probably do -- we have
25 collaborative joint project we're doing at Nine Mile

1 Point -- that would be a potential test case -- that
2 we take those scenarios, run it through this funnel,
3 and hopefully 95 percent will pass.
4 On the other side, I would say, that we
5 started the finding of these scenarios with basically
6 a range of conditions. If you recall, I said we
7 created a library of nuclear power plant fire
8 scenarios. Part of creating that was defining the
9 range: how big are the rooms; how small are the
10 rooms; what are the ranges of the ventilations. We
11 went and collected information from a dozen plants
12 that tell me, for example, what is the range of your
13 ventilation in your main control room.
14 So we collected that, and we tried to map
15 the experiments we have, which, as I said, this first
16 funnel is the mapping of experiment to reality, and we
17 didn't see hugely different things. There are
18 exceptions in the power plants, like a ventilation
19 shaft for an H-vac area, there is no very narrow long,
20 long, long, long -- those may not pass.
21 But I expect 95 percent pass because we took
22 these, checked it against this. There were no
23 surprises.
24 MR. KHALIK: But it would be a good idea to
25 document that just to see where we expect to be

1 compared to this relatively well-defined range now of
2 non-dimensional parameters in which you're saying
3 okay, you can go ahead and use these models with the
4 proviso that some of them are green, some are yellow,
5 et cetera.
6 MR. NAJAFI: I completely agree with you
7 that someday if we test that in some plant, we should
8 document it and say where we stand on that. Thank
9 you.
10 MR. APOSTOLAKIS: Now, are you done, Bijan,
11 with the summary?
12 MR. NAJAFI: I'm done if you are.
13 MR. APOSTOLAKIS: No. I'm not done.
14 MR. NAJAFI: With me.
15 MR. APOSTOLAKIS: It seems to me that we
16 have to discuss one or two things. So my
17 understanding is that the current plans are for this
18 cooperative work, collaborative work to develop a
19 user's guide whose contents are to be determined?
20 Okay. So the important thing is that this is not the
21 end, what we see now is not the end, correct?
22 MR. DREISBACH: This will be the final
23 document for the Verification and Validation. Another
24 project will create another document completely.
25 MR. APOSTOLAKIS: Called user's guide?

1 MR. DREISBACH: Whatever we call it, that's
2 what it will be. There is a concept of a user's
3 guide, and that will be a separate document, a
4 different tool, we'll say, than this tool.
5 MR. APOSTOLAKIS: Okay. There are a couple
6 of things we have to do. One is to give advise to
7 these people as to what they should present -- we have
8 an hour and a half, I suppose -- yes -- what they
9 should present to the full committee.
10 MR. DREISBACH: When Is that going to be?
11 MR. APOSTOLAKIS: October. And we are
12 writing a letter.
13 MR. DREISBACH: A couple of weeks? Early
14 October, right? First week of October?
15 MR. APOSTOLAKIS: Yes. And I would like to
16 get the opinion of the members, at least the first
17 impression as to where we stand. Now I don't recall
18 this subcommittee reviewing this in an earlier stage.
19 We never really reviewed this. Why? Why not?
20 MR. DREISBACH: We presented about an hour
21 or two. The subsequent presentation today, we did a
22 similar presentation last year in front of the Fire
23 Protection Subcommittee subsequent to asking for a
24 waiver for ACRS to review after a public comment
25 period was complete.

1 MR. APOSTOLAKIS: But we never really had a
2 meeting where you told us what you were planning to
3 do, that you were planning to calculate those epsilons
4 and this and that, so you never really got any input
5 from us on that.
6 MR. BANERJEE: Some of that information was
7 in the presentation.
8 MR. APOSTOLAKIS: Was I there? I don't
9 think I was there.
10 MR. BANERJEE: I don't recall if you were
11 there, but we --
12 MR. APOSTOLAKIS: You were already well on
13 your way though?
14 MR. BANERJEE: We -- I remember clearly
15 discussing --
16 MR. DREISBACH: Ready to go to public
17 comment space.
18 MR. APOSTOLAKIS: Yes. You were ready to go
19 to public comment, so the work had been done.
20 MR. DREISBACH: Yes. Work had been done.
21 MR. APOSTOLAKIS: What I'm saying is that --
22 MR. DREISBACH: But a very considerable
23 amount of work was done after that meeting that
24 resulted in this document. In other words, we
25 adjusted somewhat the approach --

1 MR. APOSTOLAKIS: Well, in general, you know
2 -- I know it doesn't help now, but, in general, it's
3 a good idea for projects of this magnitude to have a
4 meeting like this when you have a plan, but you hadn't
5 started the actual work, because then you have the
6 benefit of our comments, and you may or may not choose
7 to use them. But now it's difficult.
8 Okay. So what should these gentlemen
9 present at the full committee meeting which will also
10 determine the nature of the letter?
11 MR. BONACA: It seems to me, you know, if I
12 look narrowly of the objective of having V&V of fire
13 models, they have done the job to do a V&V within
14 certain contexts. Clearly, these are all matters that
15 are very empirical, it seems to me, in general. And
16 so therefore, you tend to have a very important --
17 very important that you match the physical test with
18 the model that you're developing. And that's what
19 you're trying to demonstrate. So you're really
20 forcing the user to verify that you fall within a
21 certain range because otherwise, applicability is
22 questionable. So I think in the context, I would say
23 that from a perspective of a fire protection engineer
24 at a pant, this would be a very useful tool. It
25 provides a lot of information.

1 Now I don't know at this stage of the game -
2 - what is the regulatory use of the fire protection
3 engineer at the plant. So, therefore, I can't comment
4 on the usefulness from that perspective. And maybe
5 there is still a step to be defined there as a
6 regulatory product, like a reg guide that says how
7 this can be used in support of some regulatory
8 application.
9 From a PRA standpoint, clearly there is a
10 step to be done, too. This is not usable right now.
11 And I think again, however, it's more that you need an
12 intermediate step, a regulatory step, or a definition
13 of a reg guide that would define maybe further
14 refinement of this work into some outputs that can be
15 used as inputs to a PRA. I don't know. Certainly
16 some other product in between that goes from this
17 product to be used in the field on PRA.
18 So I would give two messages in the letter.
19 I mean I don't know. You're not talking about the
20 letter right now? Or their presentation.
21 MR. APOSTOLAKIS: Happy to receive all the
22 input I can get.
23 MR. BONACA: it seems to me that, you know,
24 this is a very good first step for a V&V of these
25 products. And, you know --

1 MR. APOSTOLAKIS: The committee doesn't --
2 you remember, Mario, the committee usually doesn't
3 like to say first step. So find other words.
4 MR. BONACA: Well, it's a big step. These
5 are the fire protection -- you know, fire tools that
6 are being used by the industry.
7 MR. APOSTOLAKIS: So it's not understood
8 then that when one says I'm going to verify and
9 validate a code in general that that person must make
10 a statement regarding the uncertainty associated with
11 the predictions of the code? They don't do that.
12 I mean what they did -- first of all, I do
13 appreciate the magnitude of the effort and, you know,
14 as their reviewers also commented, and today we heard
15 this is the first time that the fire community, the
16 fire safety community has undertaken such an effort to
17 do a systematic job. But I think there is some
18 incompleteness here that is really important.
19 MR. BONACA: Trying to understand, however,
20 much of the incompleteness is something that should
21 really be part of this versus something that needs to
22 be done.
23 MR. APOSTOLAKIS: I understand that. But I
24 mean they're asking us to approve this NUREG. So if
25 we approve, it is published, and it's used. Now we

1 can screen in three other places of the letter, but
2 it's incomplete. The truth of the matter is that it
3 will be a NUREG. Now people will use it. So that's
4 the dilemma I'm facing.
5 I mean everything you said I agree with.
6 I'm sure there are fire protection engineers that will
7 find use -- and Bijan gave us good examples, I think,
8 of doing certain things that will be quick, and maybe
9 if it's conservative, you're off the hook and so on.
10 Anyway, I mean we don't have to resolve it
11 right now but.
12 MR. BANERJEE: I have a comment. Looking at
13 the title of this, you are promised more than you
14 actually get, because it's not fire models in a broad
15 sense. You really are doing the modeling of some part
16 of the problem which has simply to do with the flow of
17 the concentration fields and so on. Some of the most
18 difficult parts of this model, which is the
19 propagation of the fires, the actual heat production,
20 all these things are simply taken from empirical
21 database somewhere and stuck in here.
22 So I mean it's too ambitious to call it fire
23 models. You're not validating that part of it. That
24 part of it has simply been taken from some previous
25 experiments. And so what you're driving this with are

1 a set of experiments which were done historically and
2 the cable fires were this, that fires were that. And
3 a very large part of the uncertainty seems to me to
4 lie in that, compared to what is going on here.
5 I mean, the heat release itself, it probably
6 could be uncertain by 50 percent. I don't know what
7 the number is there. You know? So compared to that
8 uncertainty coming out of the fluid mechanics here is
9 not such a huge amount. I'm not getting the sense.
10 MR. APOSTOLAKIS: This is what they're
11 addressing, right?
12 MR. BANERJEE: Yes. What you're addressing
13 is only the uncertainty in the fluid mechanics, which
14 his great. I mean I really like that. You're
15 precisely specifying the heat input. You've got very
16 well-controlled fires. It's a very necessary step
17 that you're doing this. So the uncertainty is coming
18 out of -- I mean you've given a certain heat input
19 over a certain period of time, et cetera, you've
20 characterized this room very beautifully, got the
21 emission coefficients, all that, so it's a nice piece
22 of work, good scientific work. But it's too ambitious
23 to call it fire models. I would say this is a
24 submodel in a calculation.
25 MR. HYSLOP: Can I comment during this

1 period or is this just you guys? I think that my
2 understanding of the document was to verify and
3 validate the fire modeling codes as existed, the FIVE,
4 the EDF, those codes. And that's what they did. Now
5 clearly some codes may use a heat release rate is an
6 input, but that's the way those codes were developed.
7 So I guess, from my perspective, the title is
8 accurate, even though, you know, there were fire
9 modeling codes that were validated.
10 MR. NAJAFI: If I raise my hand can I -- I
11 would add to the second part of it, we specifically
12 say for nuclear power plant applications that it's not
13 only the scenario, it's the type of the practice.
14 Because for better or for worse, for nuclear power
15 plant practice since even the early days of Zion
16 Indian Point that George was involved in, we defined
17 the heat release rate of a fire. We did not leave it
18 whether to the comp burn or whatever with the
19 associated uncertainties, even if it's 50 percent.
20 MR. APOSTOLAKIS: We calculated it using the
21 equation you showed.
22 MR. DREISBACH: But it becomes then
23 specified in the fluid mechanics model.
24 MR. APOSTOLAKIS: Then it's input to the
25 code?

1 MR. DREISBACH: Right.

2 MR. NAJAFI: Yes.

3 MR. DREISBACH: Regardless of whether or not

4 you calculated it based on that equation --

5 MR. APOSTOLAKIS: Calculated outside?

6 MR. DREISBACH: Yes.

7 MR. NAJAFI: So the fact that we account for

8 the uncertainty of the initial fire size, the heat

9 release rate based on experimental evidence is that's

10 because how the practice in the nuclear power plant

11 fire modeling has been done for the past 10 years, 20

12 years.

13 MR. BANERJEE: Perhaps it's a matter of

14 semantics, but to me, the issue, when I think of fire,

15 I always think of how it propagates, where it goes,

16 all that sort of stuff. And this is not what you're

17 addressing here. So in the sense of a fire model, it

18 promises to anybody but maybe a very tiny group of

19 people who know precisely what you mean, which might

20 be --

21 MR. DREISBACH: Right. I think, though, the

22 term fire model, from the beginning, is somewhat of a

23 misnomer based on the way it has been applied.

24 MR. BANERJEE: Yes. It's not a fire model.

25 MR. DREISBACH: It's a smoke and heat

1 transport model.

2 MR. BANERJEE: Yes.

3 MR. DREISBACH: That's how it's used.

4 MR. JOGLAR: And we are also validating

5 selective capabilities of them. I mean maybe FDS does

6 plume, but it does other things that are not within

7 this. So calling it fire model may suggest that we're

8 validating every single aspect of that where we have

9 a list of 13 things that we are actually validating.

10 MR. BANERJEE: We're not accurate in the

11 title I feel.

12 MR. APOSTOLAKIS: Since you started this

13 Sanjoy, do you want to complete your thoughts?

14 MR. BANERJEE: Yes. This was one thought I

15 had that you are doing part of the problem. The

16 second thing I think is that given that you're doing

17 part of the problem, you have information there which

18 I feel could be helpful to present -- I don't know how

19 much more work will have to be done -- but presented

20 in a way so that we have a feel for also what these

21 predictions mean in terms of uncertainties. I know

22 you've not gone the full way, but you've already got

23 a fair amount of data. When you call something green,

24 when you call something yellow, that already gives you

25 some guidance as to how accurate, because you're

1 within certain bounds.

2 MR. DREISBACH: That was the idea.

3 MR. BANERJEE: And I don't see any harm in

4 giving that guidance to your users. You know? You've

5 already got part of the story. You haven't done what

6 we would call best estimate plus uncertainty. For

7 sure you haven't done that. But you've gone, again,

8 part of the way. So don't sell yourself short on

9 that.

10 MR. APOSTOLAKIS: And don't just send us to

11 Reference 43.

12 MR. BANERJEE: Yes. Please.

13 MR. APOSTOLAKIS: Please don't do that.

14 MR. BANERJEE: Make a self-contained --

15 MR. APOSTOLAKIS: An unreviewed reference.

16 You don't tell us what it's about. You say there are

17 ways of doing it, go to Reference 43. I mean that's

18 not for a NUREG. Are you done?

19 MR. BANERJEE: Yes.

20 MR. APOSTOLAKIS: Okay, Said.

21 MR. KHALIK: I'm not going to repeat any of

22 the comments made by my colleagues, so there are two

23 additional issues that I would like to see that came

24 up during the discussion. One of them is the

25 rationale for not using data from non-nuclear

1 industry. The comment was made that these data were
2 examined and were deemed to be either inappropriate or
3 incomplete because of lack of quantification of
4 uncertainties associated with the data. And the
5 comment was further made that that assessment was not
6 documented. So somehow a rationale for explaining why
7 we haven't expanded the database to include data from
8 outside the database that you've used would be very
9 helpful.
10 The second comment that also came up during
11 the discussion is that it would be helpful to provide
12 the underlying bases for the specified non-dimensional
13 groups and their applicability to the various models.
14 MR. NAJAFI: Can you repeat the second one?
15 MR. KHALIK: The underlying bases, I think
16 the comment was made that these just fall out readily
17 for non-dimensionalizing the Navier Stokes equations,
18 and if that is really the case, then, you know, in
19 some cases, you know, natural convection effects don't
20 appear, and the question is why.
21 MR. BANERJEE: Well, I think they promised
22 us a document summarizing either part of this document
23 as an appendix or whatever, the choice of the non-
24 dimensional groups instead of trying to read a whole
25 handbook and try to get input into that, just

1 summarizing how one arrived at these non-dimensional
2 groups and why they're felt to be the ones that are
3 important. They're not intuitively evident.
4 I mean you've got a fluid number, and
5 usually fluid numbers have to do with gravity waves.
6 So I don't understand how it actually arises other
7 than purely empirically. So I'd like to know the
8 rationale behind it. You know, fluid numbers are not
9 normally thought of as internal waves or gravity
10 waves, but why does it arise here? I'm not clear.
11 Grashof I would have believed. You know? So we'd
12 like to see that justification.
13 MR. APOSTOLAKIS: Now if I were you
14 gentlemen, I would prepare for a presentation in
15 October. Since we have a total of an hour and a half,
16 you should plan on taking maybe five, fifteen minutes,
17 no more than that. Because I am sure the other
18 members will have questions, too. Now I think, and my
19 colleagues here can jump in at any time, of course, I
20 think you should skip other statements. We want to be
21 transparent. We know that. We know what you want to
22 be.
23 Go to these are the objectives of what we
24 did. This is the result in my view, Table 3-1. Let
25 me tell you what green is. We declare this as green

1 because we did this, we had the U_c, we compared, and
2 here are a couple of examples. We call this yellow
3 plus for such a reason. A slide or two so the
4 committee will understand what your bottom line is.
5 Then it seems to me you should address the
6 issue of the user. We do this. We don't do that. We
7 plan to do it in the future, or we leave it up to the
8 user to decide. If you're clear on these things, I
9 think you will have a very understanding committee.
10 Like today, we really had to struggle to come to the
11 bottom line. And also, please address specific
12 comments like what Professor Abdet Khalik just said
13 about, you know, the dimensionalized groups. There
14 were other questions from Professor Banerjee earlier
15 about the scientific basis of certain things. I
16 assume you will address those. But I'm just giving
17 you what I think should be the overall approach,
18 because you don't have a lot of time.
19 MR. BONACA: The other thing that, you know,
20 I will suggest, you know, regarding the not using
21 information outside the nuclear. If I look at the
22 test they took, they're so specific to nuclear. And
23 I think empirically based on the models. I mean those
24 are so empirical, too, that I can understand how they
25 want to stay very close to the test. Maybe that's

1 something that you want to say.

2 MR. APOSTOLAKIS: Yes, Bijan,

3 MR. BANERJEE: -- do it because -- it seems

4 to me that that's the best justification that your

5 test which was very specific to, for example, a

6 switchgear room -- I mean they all -- and so,

7 therefore, that's why you stayed with that test, you

8 didn't go searching for outside tests of other nature,

9 because it's so unique and so specific and so

10 applicable to all the power plants in the U.S.

11 MR. NAJAFI: Do you want to also hear about

12 something you raised this morning about these

13 differences between the fire scenarios that are

14 outside of the capabilities --

15 MR. APOSTOLAKIS: Absolutely. Yes. I

16 assume that we took notes of those. Not just me. I

17 think all of us heard this, but I don't remember all

18 of them now. But I do remember that people had

19 specific questions, and we agreed that you would

20 address them.

21 MR. NAJAFI: In that presentation?

22 MR. APOSTOLAKIS: Yes. In that

23 presentation. But it's really very important, it

24 seems to me, within 15 minutes of your presentation

25 for the committee to see your final result and why,

1 why you got a yellow, what does it mean. Or whatever,
2 green, no reds.
3 And another specific issue that bothers me
4 is -- maybe you can go back and think about it a
5 little bit -- is this intrinsic model uncertainty.
6 You sort of dismiss it. And it's there. It's there
7 in your calculations. Now when you get this U_c -- I'm
8 still trying to figure out -- you know, intrinsic
9 model uncertainty means that I will have some
10 systematic overestimation or underestimation within
11 some range. Yet the U_c, isn't that what it is? A
12 bias, right, model uncertainty, you know, like FIVE-
13 Rev 1. It tends to be conservative. It over-
14 predicts, which is fine as long as I know it.
15 But the U_c has the implication that there is
16 some randomness within this range that can be up or
17 down, and I'm not sure that if you have intrinsic
18 uncertainty that's correct. In fact, over a few of
19 the slides you showed, the red curve was always above
20 the measure, which tells me that there is really a
21 tend to over estimate with some uncertainty. Okay?
22 And would I know that by just going to your table? If
23 you say yellow plus, I probably would. But in the
24 green --
25 MR. NAJAFI: That's why we use yellow plus.

1 MR. APOSTOLAKIS: But these are the kinds of
2 issues that I think we should spend some time talking
3 about.
4 MR. NAJAFI: Yes. But the only thing I want
5 to add to what you said is that I think there is more
6 concern besides some of the examples that you said
7 that is included or embedded in an uncertainty that a
8 model prediction could have, just the model
9 prediction. And that includes all the way from how
10 model matches your scenario. Because all these
11 models, as well all know, even the FDS, the most
12 complex of all of these codes, the DDCFDs, they have
13 to simplify the physics. They have to simplify it to
14 solve it. And through that simplification, how much
15 you deviate, whether it's in a steady state or the
16 transient part of the scenario, from your fire
17 scenario and actually what in reality will happen,
18 it's too uncertain. There are so many factors.
19 MR. BANERJEE: If I understand it, your
20 current model uncertainty is primarily driven by an
21 input uncertainty?
22 MR. APOSTOLAKIS: Yes. That's what it was.
23 MR. BANERJEE: Yes. That's basically so --
24 MR. APOSTOLAKIS: Primarily Q dot.
25 MR. BANERJEE: Yes. Whatever. So that is

1 leaving out, in a sense, what George, and I suppose
2 others, call intrinsic uncertainty.
3 MR. APOSTOLAKIS: But they call it
4 intrinsic.
5 MR. NAJAFI: Yes.
6 MR. BANERJEE: So in fact, when you couple
7 that to the uncertainty in the inputs, that band would
8 be larger, wider because of that?
9 MR. DREISBACH: That's why early on in the
10 presentation we characterized this uncertainty as a
11 tighter band--
12 MR. BANERJEE: Yes, I mean but you have to
13 clarify what you're doing --
14 MR. DREISBACH: -- so we have a criteria
15 that's --
16 MR. APOSTOLAKIS: But the question is, is it
17 just larger, or has it also shifted? I think it's
18 shifted.
19 MR. NAJAFI: That's why --
20 MR. APOSTOLAKIS: It moves up.
21 MR. NAJAFI: That's why I didn't disagree
22 with that that is the intrinsic uncertainty. What I
23 said is that there may be more input, more sources of
24 uncertainty.
25 MR. APOSTOLAKIS: Absolutely.

1 MR. NAJAFI: There's a lot, and it's hard
2 for me to tell always. I mean I used a good example,
3 Kevin, if I may, that he -- he doesn't know even what
4 I'm going to say -- is that there are these effects
5 near affect --
6 MR. APOSTOLAKIS: Up to this point, right?
7 MR. NAJAFI: --the near affect and far
8 affect. -- I mean these models and some of these
9 predictions, the ranges of uncertainty varies even if
10 you happen to be too close to the fire or too far from
11 the fire, if the plume happens to be next to a
12 ventilation. There are so many different things.
13 MR. APOSTOLAKIS: But the point is you -- I
14 mean maybe you're already doing it to some degree --
15 you should sensitize the user.
16 MR. NAJAFI: Yes.
17 MR. APOSTOLAKIS: Maybe the intrinsic
18 uncertainty is overwhelmed in some cases by the input
19 uncertainty.
20 MR. NAJAFI: Yes.
21 MR. APOSTOLAKIS: I'm willing to accept
22 that.
23 MR. NAJAFI: What, in my mind, we tried to
24 do as knowledgeable people of the need of the fire
25 modelers -- what I mean fire modelers is end users,

1 some fire protection guy that starts using it, and
2 people who developed the code and the theory all the
3 way from Kevin to Jim Quintiere and Craig Beyler -- is
4 that we put ourselves through that practice of using
5 these numerics so that the end user can use a product
6 that is much simpler to use.
7 So we went through that exercise of instead
8 of developing a full blown uncertainty project for the
9 fire models, for the CFAST for example, we went
10 through this numerical exercise. And basically we
11 jumped almost our uncertainty estimate into a color
12 code. We did that intrinsic in a sort of a leap of
13 faith. We said we look at these all attributes. We
14 know these models. We know the physics. We see
15 these, what they do. Some they're too far up, too far
16 low, to the left, the time actually -- we even looked
17 at the time. What if its time shifted? There's not,
18 but it's time has shifted. So we collectively took
19 that and we said in some expert panel thing, for lack
20 of a better word, and said the uncertainty is green.
21 So because right now a method that is well-
22 understood, well-accepted by everybody how to assess
23 model uncertainty, we could not point our finger to it
24 and say everybody will agree to that. So we went
25 through a pseudo expert panel and, to us, that is a

1 substitute for model uncertainty of this collective
2 team. And, please, speak up if you disagree with
3 that.
4 MR. McGRATTAN: I'll say it in a different
5 way. The big picture, the big idea here is that each
6 of these models is a collection of many, many
7 algorithms. If we tried to go through each of the
8 models and assess the uncertainty of each of these sub
9 grid algorithms and so forth -- I mean you mentioned
10 the k-epsilon parameters, we used the Smagorinsky
11 coefficients, on and on and on -- that would be just
12 an impossible exercise. So instead, we looked at the
13 measurement uncertainty, uncertainty in the
14 measurement of the inputs, uncertainty in the
15 measurements of the outputs and these experiments, and
16 use that as a guide or as a yardstick to assess --
17 this word intrinsic -- I think there's probably a
18 better word -- to assess really what the uncertainty
19 in the model prediction is by using the experiment
20 instead of trying to get into the nitty-gritty of all
21 these algorithms. That's the big idea here.
22 MR. APOSTOLAKIS: Okay. Thank you very
23 much.
24 MR. BONACA: Just a question. Are you sure
25 we have only one and a half hour?

1 MR. APOSTOLAKIS: It is usually an hour and
2 a half.
3 MR. DREISBACH: It's my understanding two
4 hours at the maximum.
5 MR. BONACA: It is two hours at the maximum
6 I think.
7 MR. APOSTOLAKIS: Well, can you check? Not
8 that it changes anything but -- well, I have a
9 question for you gentlemen. Is the NUREG approved or
10 not? And we have to say something in the letter. As
11 is, should it be issued or not?
12 MR. BANERJEE: As is?
13 MR. APOSTOLAKIS: As is.
14 MR. KHALIK: If I were to vote now, I'd say
15 no.
16 MR. BANERJEE: No.
17 MR. APOSTOLAKIS: Mario?
18 MR. BONACA: I don't know.
19 MR. APOSTOLAKIS: I don't know. That's
20 fine. Okay. Anything else that anyone would like to
21 say? Thank you very much gentlemen. Appreciate your
22 presentations, and we will see you in a couple of
23 weeks.
24 (Whereupon, the matter went off the record
25 at 2:21 p.m., and back on the record at 2:47 p.m.)

1 MR. APOSTOLAKIS: Okay. The subject is
2 NUREG-1852, Demonstrating the Feasibility and
3 Reliability of Operator Manual Actions in Response to
4 Fire. I see Dr. Lois is there. You will start the
5 meeting?
6 MR. IBARRA: Let me get a few introductory
7 remarks. Thank you very much for meeting with us. My
8 name is Jose Ibarra, and I am the Branch E for the
9 Human Factors and Reliability Branch and the Office of
10 Research.
11 Since this committee is assembled today, we
12 thought we would take the opportunity to take about
13 NUREG-1852. And the name of it is Demonstrating
14 Feasibility and Reliability of Operator Manual Actions
15 in Response to Fire. Now why do I say the name?
16 Mainly, because I think you all have heard about this
17 document, at least the technical content in the past.
18 We did brief you when we were talking about this being
19 a regulatory guide and we were talking about rule
20 making in operator manual actions.
21 This NUREG has been released for public
22 comment in the last few days and, of course, we will
23 be before the ACRS to give a briefing once we get the
24 public comments resolved. Today, we do have Dr.
25 Erasmia Lois from my staff to talk to you about the

1 technical content. And we were supposed to have Sunil
2 Weerakkody from NRR, but he has been called to do some
3 sort of briefing to the commission, but I do have Alex
4 Klein. He will talk to you about how this NUREG is
5 going to be used in the regulatory process. Erasmia?
6 DR. LOIS: Okay. Well, thank you very much
7 for the introduction. The first thing that I would
8 like to note about the NUREG-1852 that this is a
9 project of close collaboration of NRC staff
10 specialists, specifically in Iran and our contractors,
11 Sandia National Laboratories, Dr. John Forester and
12 SAIC, Alan Kolaczkowski, and as I present to talk a
13 little bit later, you will see that this is actually
14 kind of a summary of insights and lessons learned and
15 knowledge through the years by doing work on fire as
16 well as on human performance.
17 In terms of overall presentation, I'll cover
18 quickly the purpose, and then I will talk very briefly
19 about the NUREG and present a summary slide. As Dr.
20 Ibarra said, the purpose is to inform the committee
21 about this activity. This is kind of a heads up and
22 inform you about the plan to present the technical
23 content in more detail after public comment and before
24 we revise it and as well as request feedback at this
25 stage of the activity.

1 In terms of background, when the rule making
2 activity was going on for the Fire Manual Actions, we
3 developed Draft Guide 1136 with the title
4 Demonstrating the Feasibility and Reliability of
5 Operator Manual Actions in Response to Fire. And that
6 regulatory guide was providing the technical basis for
7 the rule making activity. However, the rule making
8 was stopped. On the other hand, the NRC, through the
9 exemption request, is going to help to evaluate the
10 manual actions that licenses are or have been
11 implementing to maintain and achieve -- maintain safe
12 shutdown.
13 The reg guide, DG-1136, was providing the
14 technical basis, and because of the NRC's need to
15 evaluate the human actions, we decided that we should
16 retain the technical work performed as a NUREG. The
17 objectives of the NUREG-1852 are to provide technical
18 bases, as I said, and in actuality, to be used as a
19 reference guide by the NRC staff reviewing licensee
20 submittals. And that aspect is going to be covered in
21 detail by Alex.
22 MR. APOSTOLAKIS: Erasmia, can you remind us
23 why the rule making activity was stopped?
24 MR. KLEIN: Dr. Apostolakis, I have a slide
25 on that, and I'll briefly talk about that. But to

1 answer your immediate question, when we briefed the
2 committee, I believe it was in November of last year,
3 we had indicated to you that the proposed rule was
4 withdrawn because it would no longer meet the
5 efficiency and effectiveness goal of the NRC because
6 the comments that we got back from the industry were
7 that they would still submit a large number of
8 exemption requests as the proposed rule was written in
9 the form of the proposed rule due to some issues.
10 MR. APOSTOLAKIS: Now I remember. Yes.
11 Thank you.
12 DR. LOIS: The scope of the NUREG, it does
13 not address actions needed after control room
14 evacuation, and also, it does not stop at the defense
15 and depth criteria that are actually recommended in
16 Appendix R of Section III.G.2. In terms of status, it
17 has been released recently. And as I said, we are
18 going to brief the ACRS, and we'll finalize it by next
19 spring.
20 MR. APOSTOLAKIS: Do you also plan to issue
21 a regulatory guide or just the NUREG?
22 MR. KLEIN: No. We're in the process. We
23 have a regulatory guide in existence right now. It's
24 Regulatory Guide 1.186. We're in the process of
25 revising that regulatory guide. And as I understand

1 it, there is going to be presentation in the near
2 future, I believe it may be as early as next week, on
3 a series of regulatory guides that are undergoing
4 revisions and at a high level. I think that they'll
5 introduce to the committee the revisions to Regulatory
6 Guide 1.186 and dat some future time come back to you
7 with the details.
8 MR. APOSTOLAKIS: And this regulatory guide
9 would rely on this NUREG?
10 MR. KLEIN: That's correct. The regulatory
11 guide will refer to it.
12 MR. APOSTOLAKIS: One point eight six you
13 say?
14 MR. KLEIN: One point one eight six.
15 MR. BONACA: If I remember, the bone of
16 contention was the automatic fire suppression, right?
17 MR. KLEIN: That's correct. There were
18 actually two. The condition to have automatic fire
19 suppression as required by the existing rule,
20 III.G.2., and the time margin was also an issue that
21 the industry had commented on.
22 DR. LOIS: The approach, like the Regulatory
23 Guide 1136, it's a deterministic approach. It builds
24 on existing, as I said, knowledge and experience
25 gained through the years by performing and developing

1 guidance for human performance issues and also doing
2 fire inspections and other kinds of inspections, very
3 much on human factors related guidance and industry
4 standards. In addition to the NUREG builds on a
5 review on insights and knowledge gained by reviewing
6 PRAs, hybrid PRA reports, et cetera, which address the
7 availability aspect of human performance.
8 So in many respects, the criteria that are
9 documented in NUREG-1852 explicitly document the
10 criteria that have been used so far by the staff for
11 various types of inspections of human performance,
12 including fire.
13 Now in terms of risk-informed approach,
14 because of NFPA 805 and the use of it, we plan to
15 collaborate with EPRI to develop an HRA methodology
16 that it would be used for fire-related HRA analysis.
17 MR. APOSTOLAKIS: But that will not be
18 deterministic, I hope?
19 DR. LOIS: It will be risk-informed.
20 MR. APOSTOLAKIS: HRA?
21 DR. LOIS: HRA.
22 MR. APOSTOLAKIS: So, now -- I hate to say
23 this -- the agency has three methods for addressing
24 human performance: NUREG-1852 and SPAR-H.
25 DR. LOIS: I think SPAR-H or ATHEANA or any

1 other method are methods that were developed primarily
2 on a full-power PRA analysis and fire is not a
3 measured part of it, so the hope is, and I'm going to
4 -- Bijan is here -- the hope is that the industry and
5 the NRC agree on a methodology and then expand it and
6 develop it so that it will address fire regs.
7 MR. APOSTOLAKIS: We're talking about fires
8 now.
9 DR. LOIS: Yes.
10 MR. APOSTOLAKIS: But what I'm saying is
11 that having three different methods, all NRC methods,
12 is probably not a very happen state of affairs. For
13 example, when we had the subcommittee here last
14 December, I think it was, talking about time and how
15 to handle it and so on, there was a very strong
16 argument made by Dr. Gareth Parry that in most cases,
17 the time available is much larger than the required to
18 perform an action, so we really didn't need to go to
19 a time-focused HRA method. And I see here that's what
20 you're doing. You're making sure that the time
21 available is much larger than the time required to do
22 it plus some margin.
23 But my question is why can't we use 1852 to
24 replace all the HRA models? By reading the report, I
25 get the impression that everything is fine. You

1 estimate five minutes. You double it. You compare it
2 with the time available. You can say I'm happy.
3 MR. KOLACZKOWSKI: This is Alan
4 Kolaczkowski, SAIC. First of all, let me make one
5 distinction. You're statement is correct about the
6 three methods, but this is purely in deterministic
7 space.
8 MR. APOSTOLAKIS: Understood.
9 MR. KOLACZKOWSKI: Okay. Just as long as
10 that's understood. So while there are three, ones an
11 apple and the other two are versions of oranges.
12 MR. APOSTOLAKIS: But the apple seems to be
13 solving a lot of problems, so maybe an apple a day
14 makes the oranges go away.
15 MR. KOLACZKOWSKI: You pose a very
16 interesting questing.
17 MR. APOSTOLAKIS: Thank you, Alan.
18 MR. KOLACZKOWSKI: Okay. I will say this.
19 If in the risk-informed world you do want to have a
20 better idea of what drives human performance than to
21 just dump everything into one thing called time, you
22 just have to at least ask the question, will that help
23 us learn and how to improve, or are we just trying to
24 get a number, or in this case, are we just trying to
25 pass an acceptance criteria and we don't really care

1 why the thing might take 27 minutes versus 25 minutes.

2 MR. APOSTOLAKIS: But I read very carefully

3 the Appendix to this report, which I believe you and

4 John probably had something to do with.

5 MR. KOLACZKOWSKI: I'm sure.

6 MR. APOSTOLAKIS: In fact, you are the

7 authors I believe. And you do take into account when

8 you put the margins these uncertainties. Again, the

9 question in my mind is either this document is not

10 appropriate because even with the margins as you just

11 said, there is still a probability that we'll make a

12 mistake. Or if this document is okay, I don't need

13 ATHEANA and SPAR-H, I don't need anything else. All

14 I have to do is find the available time from this

15 gentleman, the thermohydraulicist, then ask the

16 operators how much will it take you to do this. And

17 they would say 3-1/2 minutes. I double it. I triple

18 it. I'm still within the limit and I'm happy. So it

19 seems to me there is a conflict here. Either the

20 deterministic method is correct or it isn't.

21 DR. LOIS: Can I answer that?

22 MR. APOSTOLAKIS: Of course.

23 DR. LOIS: I think in this deterministic

24 space, for those actions that the time is not

25 adequate, are not going to be approved. So you can

1 conceive cases where potentially you have a task that
2 would need to be accomplished with many consecutive
3 actions, people would have to communicate, go here and
4 there, those instances, unless there is a true
5 justification that there is -- you know, if it takes
6 half an hour, you have an hour already, and, yes, we
7 are going to have the crew on shift, and yes, yes,
8 yes, yes, yes, the deterministic criteria provided
9 here shows a lot of the uncertainties that we're
10 addressing in human reliability.
11 When we do a human reliability, we don't
12 know -- there are no regulations that would ensure
13 that the best crew is going to be on shift, or it
14 won't happen at 2:00 in the morning. And we're
15 dealing with those kinds of aspects in a probabilistic
16 approach while here, a priori, we assume that are
17 going to be in place and, therefore, they're not
18 unknown anymore. So in a way, we have addressed
19 several of the uncertainties that we're dealing with
20 in human reliability through this establishment of the
21 criteria and working in deterministic ways.
22 MR. APOSTOLAKIS: Well, I must say that I
23 don't quite agree with that, because this report has
24 a very detailed discussion of the various
25 uncertainties. And, you know, it goes into things

1 that are very nice actually, that the crew may be a
2 mixture of very competent people and novices and so
3 on. And then it argues, you know, that why the
4 margins that are proposed are appropriate. In fact,
5 I see here factors that cannot be created in the
6 demonstrations have to be taken into account, the
7 operators may need to recover from or respond to
8 unexpected difficulties, there will be variations in
9 fire and related plant conditions, so there is really
10 a very nice discussion of all the uncertainties and
11 what the demonstration can or cannot demonstrate.
12 Typical and expected reliability among individuals, my
13 goodness, look at all these bullets. And then, bang,
14 here is a margin that takes care of all of this. So
15 why do ATHEANA then?
16 MR. FORESTER: I'm John Forester. A couple
17 of comments where I think this may be a special case.
18 One is the diagnoses for most of these types of
19 actions are very simplistic in a sense that many of
20 them are preventative actions so that the cue for the
21 actions is simply the existence of a fire. So it's a
22 very benign kind of diagnosis in many cases.
23 And secondly, even though Gareth Parry is
24 probably correct in a sense that there is a lot of
25 time available for many of these actions, there are

1 cases where there is time pressure, and there could be
2 more complex diagnoses involved. So in those
3 particular kinds of situations, I'm not sure this type
4 of model goes quite far enough.
5 MR. APOSTOLAKIS: Yes. But I mean if we are
6 approving a model that is applicable to fire
7 conditions, which, you know, are not a simple thing,
8 and it's a deterministic model, either it is adequate
9 or it isn't. Now the approach here is fairly similar
10 to the ATHEANA approach or scenarios in the sense that
11 you have the expected sequence, and then you try to
12 think of variations. You don't call it that, but it's
13 really the same thinking. But at some point it seems
14 to me that the NRC or the management should think
15 about the whole issue of human reliability and what
16 are we doing as an agency. I mean having one model in
17 Idaho, two models here really different, we have to
18 settle on something at some point. And then we have
19 EPRI with its own model. So I don't know what to make
20 of all this. I mean we really need some sort of
21 coordination. Alan, you want to say something?
22 MR. KOLACZKOWSKI: Yes. Alan Kolaczkowski.
23 I guess the only think I would add is that in a way,
24 I view this as being the same thing as -- think where
25 the agency was prior to risk-informed regulation

1 process. We had deterministic criteria that we
2 believed -- if we had, you know, single failure proof,
3 a certain amount of redundancy diversity had to be
4 met, et cetera, et cetera, those were very explicit
5 criteria, and if the plant was designed that way, at
6 least, even if we didn't really say this, in theory,
7 we thought the risk of a nuclear - of a severe
8 accident will be low.
9 Now came along the PRA process where then we
10 actually assigned -- we built logic models and built
11 databases, et cetera, and said well, what is that
12 residual risk. And in a couple of cases, we actually
13 found out our belief that we had, by using single
14 failure criteria, et cetera, we had kept the risk low.
15 We said, hmm, maybe we do need an additional ATWAS
16 rule, maybe we do need an additional station blackout
17 rule, because there's a few holes there that we hadn't
18 quite handled. I view this as the same. If you're
19 going to remain deterministic space, that in order to
20 handle these uncertainties, just as we had
21 uncertainties about well, how much redundancy should
22 we have, is single failure criteria enough, or do we
23 need a double failure criteria. We made a decision
24 and we moved on in the regulations.
25 Here we're making a decision. We're saying

1 we're going to use time as a surrogate to capture all
2 these other things. We believe if you've done that,
3 that the risk of this manual action not being reliable
4 will be low. But until you then actually do HRA
5 modeling, through whatever methods, CPDT or ATHEANA or
6 whatever, can you really say, so what is that residual
7 risk that remains, and in fact does this rule do what
8 we think we want it to do. I just see that that's the
9 parallel. I don't know if that helps or not.
10 Now it doesn't address your question of
11 given you decide to do NFPA 805, and you're going to
12 do an HRA, why do we have 40 different HRA methods out
13 there. I realize it doesn't address that question.
14 DR. LOIS: And I hear it will be in a case
15 where the industry and the NRC hopefully will agree on
16 the methodology at least for --
17 MR. KOLACZKOWSKI: Yes. At least the fire.
18 We're actually going to try to have industry and the
19 NRC agree on a method.
20 MR. APOSTOLAKIS: So you are on your way of
21 having a collaborative agreement with them?
22 MR. NAJAFI: This is Bijan Najafi again. I
23 just want to caution that this collaborative project
24 has multiple steps to start and kick off a project,
25 and we are in a planning phase of this project at this

1 time. So other things need to and should happen
2 before we actually put pencil to paper start of next
3 year. It is critical to the industry. I guess we
4 recognized that this is an important piece after we
5 finished our previous work. Because of the manual
6 action, because of the PRAs that are being done, this
7 is an important critical piece. But still there are
8 steps that have to happen before we can actually
9 start. I just wanted to make that clear. Thank you.
10 DR. LOIS: Me being on the optimistic side,
11 I'm saying it --
12 MR. APOSTOLAKIS: So this NUREG is for
13 licensees who remain in the deterministic domain?
14 MR. KOLACZKOWSKI: They're not going to do
15 805. They decide they're going to stay with Appendix
16 R.
17 DR. LOIS: It's not for the licensees.
18 MR. KOLACZKOWSKI: That's what this NUREG is
19 for.
20 DR. LOIS: This is technical guidance for
21 the NRC staff evaluating the licensee applications or
22 requests to have manual actions as a means of
23 maintaining how shutdown --
24 MR. APOSTOLAKIS: The thing is that I'm
25 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.

1 DR. LOIS: We have steps to get there.

2 MR. KLEIN: If I could just emphasize the
3 use of this NUREG, which I'll talk about in my
4 presentation. It is for the NRR staff to use if and
5 when we receive these exemption requests that the
6 licensees have indicated that they would submit to us.
7 And it's for those licensees who are under a
8 deterministic licensing basis today.

9 MR. APOSTOLAKIS: But conceptually, it
10 creates a problem.

11 MR. KLEIN: I understand.

12 MR. APOSTOLAKIS: A lot of the stuff we're
13 doing is driven by legal requirements, but this
14 committee has to point out the logical
15 inconsistencies. Let me speed it up for you.

16 DR. LOIS: Sure. Well, probably most of the
17 slides will not be needed to be covered. Just
18 quickly, the NUREG has both visibility and reliability
19 criteria, and it's two parts. One documents the
20 criteria and why we have -- what is the technical for
21 bases for those. And then guidance for implementing
22 it.

23 In terms of difference with the reg guide
24 draft guide 1136 is the fact what we've said before.
25 That for a time margin, we were recommending in the

1 draft reg guide a factor of two, and we're not doing
2 it here. But we insist the NUREG requires extra time,
3 but then there are various methods how you can
4 demonstrate extra time, and the licensees would have
5 to justify their method and why that time is adequate.
6 And the change was done because of commission
7 direction and, I guess, comments on the draft reg
8 guide.
9 These are the criteria. I don't have to
10 size them. In terms of feasibility, probably it's
11 worthwhile to mention that an action is considered
12 feasible if it can be shown that it can be
13 accomplished within the estimated time available, and
14 the estimation comes from analysis performed, and in
15 that estimation the criteria required to have taken
16 into consideration uncertainties that are fire-related
17 such as nature of the fire, fast, slow, et cetera.
18 Also to be taken into consideration is the time that
19 it would take to diagnose the event. And in a
20 nutshell, the last criterion is to perform
21 demonstrations. And, therefore, the estimated time
22 has to be compared with the time that the
23 demonstrations showed that it would take and make sure
24 that the estimated time is large.
25 Now, licensees can come in and say that we

1 use conservative estimations and, therefore, our
2 estimations envelop all of those uncertainties. In
3 those cases, they would have to provide the
4 justification on how these are enveloped. In terms of
5 reliability now, we address more uncertainties with
6 respect to t--
7 MR. APOSTOLAKIS: Excuse me. All these
8 estimates come -- I mean if I'm a licensee and come to
9 you -- and you have a couple of examples here -- and
10 say -- yes, I follow your diagram, and I estimate it
11 will take me a minute and a half to do this manual
12 action, does the NRC take that and accept it, or they
13 have to actually show people running to do that in a
14 minute and a half? What is the rule of the game here.
15 MR. KLEIN: From an NRR [perspective, when
16 we review license amendments and exemption requests,
17 this information, of course, provided such as you
18 noted, if the information needs to be clarified, needs
19 to be substantiated, we will go - and it has not
20 already done so in the submittal, we will go back to
21 the licensee to request additional information. Would
22 we ask them for a demonstration? That's hard o say.
23 I think it depends on the exact exemption and the
24 conditions under which they're requesting it. There
25 might be situations when it's a very clear simple

1 operator manual action, and the staff may or may not
2 ask for a demonstration. If it's a complicated one,
3 again, it depends upon the comfort level of the
4 reviewer also. And he may or may not ask to have the
5 licensee demonstrate to him or her that the action can
6 take place in the time estimated.
7 MR. APOSTOLAKIS: The word demonstrate is
8 used a lot in the document, and I thought it meant
9 that they would actually have to do it, and you would
10 be observing it, but you are saying no.
11 MR. KLEIN: We may or may not observe it.
12 I think that the criteria does require the licensee to
13 demonstrate that he can, because the licensee
14 otherwise cannot estimate the time that it would
15 actually take to perform the operator manual actions.
16 Whether the staff would actually observe it, because
17 we're at headquarters, again, we would most like
18 likely not directly observe it. Again, I would have
19 to go back to an example where if the situation does
20 warrant it, we may request that of the licensee, but
21 I don't, offhand, see that at this point.
22 DR. LOIS: So although we have a criterion
23 for the licensee to be able to demonstrate the
24 feasibility and reliability of the action, that
25 doesn't mean the NRC is going to ask the licensee to

1 demonstrate every action that they are doing.

2 MR. KLEIN: Right. Through our Reactor

3 oversight process --let's assume that the licensee has

4 been granted the exemption request. Through the

5 Reactor oversight process, an inspector could go in

6 and see the licensee, and in the process of that

7 inspection, could ask the licensee to demonstrate the

8 feasibility and reliability of their operator manual

9 action through a demonstration, in other words,

10 through a walkthrough with the inspection and

11 demonstrate to the inspector that the timing is as

12 indicated in the license amendment submittal.

13 MR. APOSTOLAKIS: But it may be very

14 difficult to create fire conditions. I mean

15 environmental affects, so I don't know what kind of

16 demonstration that would be.

17 MR. KLEIN: Oh, absolutely. It is very

18 difficult. We have the same situation with fire

19 brigade drills today, same thing. Licensees do their

20 best in terms of simulating the conditions for fire

21 brigade drills, and I see this as a very similar

22 situation. And John and Alan may be able to elaborate

23 on that for me, but I believe that in terms of the

24 environmental conditions and so forth, I think that's

25 why we have the time margin built in, because of those

1 uncertainties.

2 MR. APOSTOLAKIS: The main message I get

3 from this NUREG is that whatever the estimated time

4 is, you double it. Essentially, that's what you say.

5 --

6 DR. LOIS: That used to be the case for the

7 draft regulatory guide, and we have that included as

8 an example, as one way for the acceptability for the

9 time margin. But it doesn't mean that licensees would

10 have to follow that example.

11 MR. BONACA: You know, time is not the only

12 issue here, however. I mean what your concern -- I

13 mean even if you were observing an exercise, you're

14 measuring the time, you're presuming that everything

15 will work that way that they've developed in the

16 scenario. In reality, what you're concerned about is

17 fire-related issues. You may have a man down that is

18 burning or whatever and, you know, are you considering

19 events like that? You have to. And that will affect

20 the time in a way that is more difficult to evaluate.

21 MR. APOSTOLAKIS: That's why they double it.

22 MR. FORESTER: John Forester. Could I

23 comment, please? I think the guidance suggests that

24 they actually conduct a demonstration if they want to

25 take credit for the fire manual action, so the intent

1 is that they would conduct a demonstration, and they
2 would try and simulate as many aspects of the actions
3 as possible which means the diagnosis and what it
4 takes to implement that. And to the extent that they
5 can simulate fire effects, that would be a good idea.
6 But the goal then is to get a -- and, you know,
7 obviously under -- if they're at full power, they may
8 not be able to open certain valves that may be
9 required in the case of the fire, so they have to
10 estimate certain aspects that's involved in conducting
11 the demonstration.
12 But at the end of that, okay, they've
13 demonstrated that they can carry out this action and
14 do all this stuff, with some estimations along the
15 way, in a certain amount of time, and then at the end
16 of that, then the consideration is that but there has
17 to be some extra time, again, to cover the factors
18 they couldn't simulate, like someone's down, there's
19 water on the floor. That's the things that are to be
20 covered by the extra time. But they need a basis to
21 establish from the demonstration to be able to then
22 take these other things into account and figure out
23 how much extra time they need.
24 MR. APOSTOLAKIS: Well, the extra time it
25 seems to me is really guidance from you, the margin.

1 That's why I say that I get the impression that you're
2 really recommending doubling the time.
3 MR. FORESTER: That's what we started with
4 was suggesting factor two based on the process we
5 used, but the notion was is that maybe in all cases,
6 that wouldn't be necessary to have that level, that
7 large a factor. But, again, the main thing is for
8 them to consider all these other things that might go
9 wrong that they couldn't do in a demonstration, and
10 they want to make sure they do have enough time to
11 cover those aspects, whatever that time needs to be.
12 If they do that analysis and look at all those issues,
13 then whatever time, they need to make sure they have
14 enough.
15 MR. KLEIN: I think the discussion of the
16 time factor of two in the NUREG I think was an effort
17 to preserve the resources that were expended and the
18 expert elicitation panels work done as part of the
19 draft reg guide. It is not in there as a hard and
20 fast criterion for the NRR staff to use to say to a
21 licensee your time margin shall be two times. It is
22 not.
23 MR. APOSTOLAKIS: I know it is not intended
24 to be, but I mean it seems that that's roughly what
25 would be an acceptable margin.

1 MR. KLEIN: I think --

2 MR. APOSTOLAKIS: If a licensee comes to you
3 and has multiplied the estimated time by 1.2, I can
4 see the reviewer saying, "For heaven's sake, you know,
5 it seems that two is the appropriate number and you go
6 down to 1.2, why?" I mean there will be a lot of
7 discussion, but I appreciate that's something that's
8 a subjective judgment.

9 MR. KLEIN: And certainly two is not a
10 maximum either. I want to emphasize that, too. And
11 I think that the commission, in their response back to
12 the staff when we went out for the proposed rule, made
13 a very similar comment in their SRM back to the staff.

14 MR. APOSTOLAKIS: Yes. Okay.

15 MR. KOLACZKOWSKI: Alan Kolaczkowski. I
16 guess, just for the record, yes, I want to make sure
17 it's clear. This does not recommend even the factor
18 of two.

19 MR. APOSTOLAKIS: Yes.

20 MR. KOLACZKOWSKI: And if a licensee came
21 and said, well, I multiplied it by 1.2, hopefully the
22 submittal would say we think this is appropriate
23 because to the best of our ability to measure,
24 estimate, whatever, those uncertainties and their
25 effects, we think we can justify, we will show you why

1 we think just a multiply of 1.2 envelops those. And
2 if they can provide adequate justification in the view
3 of the reviewer, than that's going to be good enough.
4 DR. LOIS: So we have criteria for
5 environmental factors. I don't think I should --
6 unless the committee has any questions on these --
7 equipment functionality and accessibility,
8 availability of indications, capability for
9 communicating during a fire event, the fact that
10 portable equipment needed and personal protection
11 equipment needed, criteria for those. I'm just
12 skimming through. Unless you have any questions, I
13 don't want to --
14 MR. APOSTOLAKIS: I do.
15 DR. LOIS: Yes?
16 MR. APOSTOLAKIS: It seems to me that what
17 a lot of this report does is tries to figure out
18 scenarios, possible performance-shaping factors and so
19 on, and ATHEANA does this very well. Why didn't you
20 bring some of the ATHEANA methods here?
21 The first part of ATHEANA with scenario development
22 has nothing to do with risk, so it would be very
23 helpful, it seems to me, to bring some of the ATHEANA
24 methods to this.
25 MR. KOLACZKOWSKI: Well, again, we didn't --

1 we wanted to keep this in deterministic space. We
2 don't want the licensee to provide a submittal where
3 they've done some ATHEANA analysis.
4 MR. APOSTOLAKIS: But ATHEANA is --
5 MR. KOLACZKOWSKI: But if your point is that
6 we sort of think along the same lines of an ATHEANA or
7 even SHARP-1 or whatever that gets into investigating
8 what's important, what are the important PSFs,
9 whatever, you could say that's already inherently been
10 done, and the result is we think these 11, or whatever
11 it is, criteria capture, if you will, in HRA
12 terminology, the PSFs that would be important for
13 manual actions.
14 MR. APOSTOLAKIS: Yes. But I mean it seems
15 ATHEANA is already in existence.
16 MR. KOLACZKOWSKI: Yes.
17 MR. APOSTOLAKIS: And it would help to bring
18 that in here and also avoid creating this impression
19 that we have three different ways of doing things.
20 MR. KOLACZKOWSKI: Okay.
21 MR. APOSTOLAKIS: But ATHEANA's approach for
22 determining scenarios, I think, is its strength, and
23 that would be very useful here. I'm not saying you're
24 not doing it, but I think it would be very -- and also
25 you have the various possibilities in text form, using

1 eventries would be a much nicer way to display them.
2 Let's see. There was something else.
3 Now the experts, are we going to talk about
4 the experts?
5 DR. LOIS: No. I was not planning to cover
6 that. I mean how we did the expert elicitation to
7 come up with this margin of two, I'm not prepared. If
8 --
9 MR. APOSTOLAKIS: Yes. But if I raise
10 questions, are you guys going to answer them?
11 DR. LOIS: Sure. Just close the --
12 MR. APOSTOLAKIS: I'm sorry? Yes. If
13 you're done, you're done.
14 DR. LOIS: Okay.
15 MR. KOLACZKOWSKI: I think we're done
16 basically -- Alan Kolaczkowski -- I think because --
17 as far as all the other criteria go, and I don't want
18 to absolutely speak for industry, but I think the
19 indication is that industry and NRC are not at odds on
20 all the other criteria, maybe with the exception -- I
21 mean there's still a little discussion about the
22 demonstration and whatever. But other than that, I
23 think, yes, they all recognize you got to have cues to
24 even know to take the action. You got to have the
25 equipment available. You got to have communication so

1 you can talk. I don't think industry and NRC are at
2 odds at all on most of the criteria. That's why I
3 wanted to spend a little more time revisiting the time
4 margin stuff. And, again, the expert panel stuff, the
5 factor of two that you find in the Appendix is there
6 only as an illustration and not something that we
7 expect the licensee to duplicate or even use for that
8 matter if they choose not to.
9 MR. BONACA: I mean, if I remember, again,
10 the requirement still is that they operate -- that the
11 plant will have fire manual action -- I mean automatic
12 fire protection, right? These are exemptions that the
13 licensee wants to have? I mean I don't want to put --
14 MR. KLEIN: That's correct. If a licensee
15 wishes to use an operator manual action in lieu of the
16 protection requirements under III.G of Appendix R,
17 III.G.2 which requires -- I'm sorry?
18 MR. BONACA: Which is automatic detection
19 and suppression?
20 MR. KLEIN: When you have a situation where
21 you have redundant trains in the same fire area, and
22 you have one hour fire wrap or 20 feet of separation,
23 the regulations today require licensees to have an
24 automatic detection and suppression system in that
25 fire area, yes.

1 MR. BONACA: And now they won't take an
2 exception or try?
3 MR. KLEIN: If a licensee wants to come and
4 in lieu -- for example -- I'll give you an example --
5 in lieu of a one-hour fire barrier -- no, let me
6 withdraw that. Actually, let me use the example of a
7 three-hour fire barrier. Right now, the regulations
8 under III.G.2, if a licensee has redundant trains in
9 the same fire area and has one of those trains wrapped
10 with a three-hour fire barrier but now wishes to
11 remove that three -- or no longer take credit for that
12 three-hour fire barrier, that licensee might want to
13 come in for an exemption request. But, because he
14 does not have detection and suppression in that fire
15 area, and the staff believes that there is -- the
16 consideration of defense in depth that the licensee
17 needs to address is why the staff had put that in as
18 a condition as part of the proposed rule. So --
19 MR. BONACA: Suffice it to say that it seems
20 to me because they want to avoid this requirement,
21 which I always felt was sensible, the burden is on the
22 licensee to assure -- I mean I want to make sure that,
23 you know, the requirement you make for demonstration,
24 that human action is not only feasible but reliable,
25 are strict enough, and they are not going to be

1 negotiating now, you know, small fractions of time,
2 but that's what's going to happen. That's what's
3 going to happen, because now the whole issue has
4 become reliable manual action, and we forget that
5 really we are protecting certain vital areas where the
6 redundant trains are running.
7 MR. KLEIN: That's correct. We have not, as
8 of yet, as far as I'm aware, seen an exemption request
9 since the proposed rule has been withdrawn, so I can't
10 tell you at this point. I have no experience at this
11 point. No database.
12 MR. BONACA: I understand that. I was just
13 saying that as part of this, I would not have any
14 hesitation to have very strict requirements on time
15 available, because that's all you got --
16 MR. KLEIN: That's correct.
17 MR. BONACA: -- as an alternative to a
18 sensible requirement of protecting an area with
19 redundant trains. That's all you got is there, and
20 they don't want to have automatic action.
21 MR. KLEIN: That's correct. That's why the
22 staff had the position with the proposed rule that a
23 licensee have detection and suppression in that fire
24 area.
25 MR. BONACA: Right. But this is --

1 MR. KLEIN: You couldn't simply rely on an
2 operator manual action to safely shut down your plant.
3 MR. BONACA: But you're doing this NUREG
4 because the industry said, no, we're not going to do
5 it --
6 MR. KLEIN: I think the NRR staff had --
7 DR. LOIS: You want to do why don't --
8 MR. KLEIN: I can -- well, actually, I've
9 done most of my presentation at this point. The staff
10 had requested this research, the NRR staff did,
11 because we wanted to have a consistent set of criteria
12 for any future licensing amendments that might come in
13 to the staff as indicated by the industry once we
14 withdraw this proposed rule. So this is part of a
15 tool, if you will, for the NRR reviewer to evaluate a
16 licensee's amendment request for the use of operator
17 manual action, along with the requirement that's
18 currently in the rule today for detection and
19 suppression.
20 Now that's not to say that a licensee can't
21 demonstrate to us that the requirement for detection
22 and suppression could also have an exemption request.
23 Again, it depends on the specific situation.
24 MR. BONACA: I was pointing out that I
25 wouldn't be to shy to recognize that you are

1 addressing the defense in-depth issue here and, you
2 know, I think these time requirements should be strict
3 requirements.
4 MR. KOLACZKOWSKI: No. We pointed out at
5 that beginning of this presentation, the NUREG does
6 not address the defense in depth part. You're going
7 to have to go to something else to address the defense
8 in depth part. The NUREG is purposely not addressing
9 that part. It's only on the manual action itself.
10 MR. BONACA: I guess I was thinking that
11 the time is the issue that provides some margin here
12 so.
13 MR. KLEIN: Good afternoon. My name is Alex
14 Klein. I'm here standing in for Sunil Weerakkody who
15 is at a commissioner briefing currently. I am
16 actually on rotation right now in the office of
17 research, but I'm here as a representative of NRR and
18 of Sunil to provide you with, I guess, of the planned
19 use of this NUREG by the NRR staff. And, of course,
20 we've discussed in some detail several of my slides
21 already, so where that's the case, I'll try and
22 proceed smoothly and quickly through those.
23 He's done a fancy way here. I see that.
24 Sunil didn't tell me I have to press the button
25 several times. Well, good for him. I guess he wanted

1 to add a little big of a pizzaz to his presentation.

2 MR. APOSTOLAKIS: He always does.

3 MR. KLEIN: What I want to do -- and let me

4 just press the button so you see them all. This

5 slide is really to indicate to the committee that with

6 respect to operator manual actions, there are a list

7 of documents that we use. We, of course, have 10 CFR

8 50.48, Fire Protection, under which falls the

9 reference to Appendix R.

10 We recently issued a regulatory issue

11 summary, 2006-10, which basically outlines the staff's

12 expectations with regard to Appendix R III.G.2 and

13 operator manual actions. This (RIS) was issued

14 following the withdrawal of the operator manual

15 actions rule. And we mentioned this to the committee,

16 that we would be issuing a generic communication to

17 the industry, to reiterate and to re-emphasize back to

18 the industry the compliance expectations for the use

19 of operator manual actions under Appendix R. It also

20 discussed some enforcement discretion policy changes.

21 And it also discussed compensatory measures and

22 corrective actions required by licensees who currently

23 used unapproved operator manual actions.

24 I mentioned the Standard Review Plan, 9.5-1,

25 and the revision to the RG 1.189. The RG revision

1 1.189, as I indicated to you, will be coming to the
2 committee at some point in the future. We're also
3 revising the SRP, of course, to match and be
4 consistent with the things that we do in operator
5 manual actions and in the circuits arena. And that's
6 also a near-term activity. I believe that the
7 revisions are ongoing right now.
8 Let me go to the next slide. Some of the
9 supporting documents that we use, again, the RG. We
10 have criteria for inspectors in the inspection
11 procedure, 7111.05, Fire Protection. Actually, there
12 should be a T at the end of that point 05. That's
13 been in existence, I believe, since the year 2003.
14 And that's used by inspectors to determine the
15 acceptability of operator manual actions as a
16 temporary compensatory measure while licensees go
17 through their corrective action program and bring
18 themselves back into compliance with the rule and
19 their commitments.
20 We have, of course, the NUREG that we just
21 talked about.
22 MR. APOSTOLAKIS: Is it RG 1.189 or 6?
23 MR. KLEIN: If I misspoke, it's 1.189. I'm
24 sorry. If I said, 1.186, then I misspoke. It is
25 1.189.

1 This speaks to Dr. Bonaca's question with
2 respect to defense in depth and so forth. The NUREG-
3 1852 doesn't mention and doesn't obviate the need for
4 detection and suppression. That comes out of a
5 different document or set of regulations that we have.
6 Of course, it's embedded in Appendix R III.G.2 as I
7 indicated.
8 We talked about this next slide, RG 1.189,
9 with respect to the time margin. What we're
10 emphasizing is that, again, it speaks to this defense
11 in depth issue that replacing certain fire protection
12 systems or features such as a three-hour fire-rated
13 barrier with an operator manual action we believe is
14 typically unacceptable where redundant divisions
15 required for safe shutdown are in the same fire area,
16 unless, of course, alternative or dedicated capability
17 is provided under III.G.3 of the rule which, by the
18 way, also requires detection and suppression.
19 MR. BONACA: But you still have an
20 exemption.
21 MR. KLEIN: That's correct. The licensees
22 are free to submit exemption requests to the staff
23 with respect to Appendix R. That's been a
24 longstanding -- I believe there's a court case that
25 actually provided that policy with respect to Appendix

1 R, because it is a back-fit to licensees, the III.J
2 and O sections of Appendix R.
3 With respect to the use of NUREG 1852, I
4 think I indicated to the committee already that these
5 are for exemption requests to be used by the NRR
6 technical staff to use as a consistent way to review
7 the use of operator manual actions by licensees in
8 future licensing amendments. As I indicated to you,
9 as far as I am aware, we have not seen any. But then
10 again, I've been in Research for three months so.
11 MR. APOSTOLAKIS: The last sentence there is
12 bothersome -- that they may use 1852 even in risk-
13 informed evaluations. I thought you guys said no
14 earlier?
15 MR. KLEIN: Let me take a moment if I could
16 and take a look at Sunil's handwritten notes here.
17 DR. LOIS: Well, qualitative insight is
18 needed. Well, this is supplemental information.
19 MR. APOSTOLAKIS: I don't know what the
20 qualitative insight is. I mean what if they come in
21 and say, look, we calculated all these times, we added
22 the extra margin you guys want? They're okay.
23 DR. LOIS: But it would be risk-informed
24 approach.
25 MR. APOSTOLAKIS: Allowed in a risk-informed

1 environment. In other words, they may say here is a
2 sequence of events in my fire PRA. I calculate the
3 probabilities of the initiator and other things, and
4 here is a manual action of which I will assume has a
5 probability of zero for failure, because I did what
6 NUREG-1852 said for a very low probability of failure.
7 So the probability of a sequence is everything else.
8 That obviates the need for an HRA.
9 MR. KLEIN: It may very well with respect to
10 a qualitative evaluation. And I think that's what
11 this bullet is intended to convey through a
12 qualitative evaluation.
13 MR. APOSTOLAKIS: Thank you.
14 DR. LOIS: Another way to look at that could
15 be that my performance shaven factors are the ones
16 that are documented in the criteria in doing an x
17 amount of reliability analysis.
18 MR. APOSTOLAKIS: But for the human
19 reliability analysis, I have a whole method for
20 finding these things. And I don't need to go to 1852
21 to get them.
22 DR. LOIS: But that method would tell you to
23 look at these things that we're documenting in 1852.
24 MR. KLEIN: I think that's the intent of
25 this bullet.

1 MR. APOSTOLAKIS: Using it only for
2 exemptions in the deterministic space, so that changes
3 the rules of the game. So you're not asking for a
4 Letter now?
5 MR. KLEIN: No, we're not. I believe that
6 this bullet speaks to, again, a qualitative kind of an
7 insight in a deterministic license amendment request.
8 MR. APOSTOLAKIS: Yes.
9 MR. KLEIN: I think that was the intent of
10 this bullet.
11 There are a couple of limitations with
12 NUREG-1852 that we wanted to convey to the committee.
13 With respect to the first one, the criteria in NUREG-
14 1852, again, is not intended to apply to main control
15 room abandonment-type situations where the licensee
16 would have to go to his remote safe shutdown panel.
17 In other words, the timing and the considerations of
18 the criteria as the licensee abandons the control room
19 and goes to the remote safe shutdown panel, we do not
20 intend to apply NUREG-1852 to that because of a
21 previous generic communication under Generic Letter
22 8610 which addresses that question.
23 Again, the second bullet also doesn't --
24 again, we talked about the fact that it doesn't
25 address detection and suppression. That requirement

1 for detection and suppression, which the NRR staff
2 believes is a defense in dept item is under the
3 existing regulations of Appendix R III.G.2. And
4 again, it's under the purview of the SRP RG 1.189.
5 And it's reiterated in the RIS 2006.10.
6 MR. BONACA: But then if I apply for
7 replacing my automatic actuation with manual action,
8 don't I replace -- I mean manual action would not
9 establish defense in depth. It clearly replaces
10 that, right? It replaces the -- I mean -- I'm trying
11 to understand --
12 MR. KLEIN: My understanding is that
13 licensees would substitute an operator manual action
14 for a fire barrier or a 20-foot separation for
15 example. And that they would not substitute -- I
16 can't think of a situation where they might substitute
17 an operator manual action in lieu of a automatic
18 suppression system. They may. And if that's the
19 case, then the staff here would look at that defense
20 in depth aspect or the loss of that automatic
21 suppression system. We would then look at, okay, what
22 is balanced against that. Is the licensee proposing
23 to maintain a one-hour fire barrier? Has he
24 adequately justified through a fire modeling, if you
25 will, and so forth what types of fires might occur in

1 there? Are they much less than the one-hour rating?

2 MR. BONACA: But my understanding is that

3 there will be applications like that.

4 MR. KLEIN: There may very well.

5 MR. BONACA: Because, I mean some of them,

6 by the current requirements, they'll have to install

7 sprinkler systems in areas where they don't have them.

8 MR. KLEIN: That's correct. If a licensee

9 currently today has no detection and suppression

10 system in there, he most likely has three-hour fire

11 barriers in that location right now.

12 MR. BONACA: Yes.

13 MR. KLEIN: And so the request would come in

14 to use an operator manual action in lieu of that

15 three-hour barrier. Now the staff would then look,

16 okay, is the licensee proposing to provide detection

17 and suppression along with that operator manual action

18 in lieu of that three-hour barrier. If not, then the

19 staff, of course, would look at the defense in depth

20 aspect of the lack of detection and suppression in

21 that area with only the use of an operator manual

22 action. The staff is, of course, very concerned about

23 the erosion of defense in depth in that situation.

24 MR. BONACA: What do you mean by they would

25 look at it?

1 MR. KLEIN: They would consider that as
2 part of the -- they would review that. They would
3 evaluate it as part of that license amendment and
4 determine whether or not the licensee has adequately
5 justified whatever it is that they're asking an
6 exemption for.
7 MR. BONACA: But NUREG-1852 will provide the
8 base for this evaluation?
9 MR. KLEIN: NUREG-1852 will provide the
10 bases for the operator manual action itself only. It
11 does not provide the bases for the exemption from
12 detection and suppression. That comes out of the
13 Appendix R III.G.2 rule. And that is the last slide
14 that I have.
15 MR. APOSTOLAKIS: Any other commends form
16 the members? Staff? Thank you very much.
17 MR. KLEIN: Thank you.
18 DR. LOIS: Thank you.
19 MR. APOSTOLAKIS: So this is the end of the
20 subcommittee meeting.
21 (Whereupon, at 3:47 p.m., the foregoing
22 matter was concluded.)
23
24
25

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Reactor Safeguards Reliability and Probabilistic Risk Assessment

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Eric Hendrixson
Official Reporter
Neal R. Gross & Co., Inc.

NUREG-1852
Demonstrating the Feasibility and Reliability of Operator Manual Actions In Response to Fire

Jose Ibarra and Erasmia Lois,
Office of Nuclear Regulatory Research

Presentation to ACRS Fire Protection Subcommittee
September 21, 2006

NUREG-1852

- Purpose of the briefing
- NUREG-1852
  - Background
  - Objectives and status
  - Approach
  - Overview
    - Discussion of each criterion
  - Summary

Purpose of the Briefing

- Inform the subcommittee about this activity and our plans to present the technical content of the report in detail after public comment

- Request feedback at this stage of the activity

NUREG-1852--Background

- Draft Reg Guide-1136, "*Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire*," July 2005, was developed in support of the fire manual actions rulemaking
- Rulemaking activity was stopped
  - However, manual actions are/will be used by licensees
  - NRC staff will make decisions on the feasibility and reliability of proposed actions to achieve/maintain safe shutdown
- DG-1136 was providing technical bases and guidance for the "acceptability" of such actions
- Need to retain the technical work and guidance developed for staff support

NUREG-1852--Objectives and Status

- Objectives
  - Provide technical bases and guidance for justifying that manual actions are both feasible and reliable
  - To be used as reference guide by the staff reviewing licensee submittals
- Scope
  - Does not address control room evacuation
  - Does not establish defense-in-depth criteria to show that manual actions can substitute regulatory requirements (III.G.2) for fire protection
- Status
  - Released for public comment, Sept 2006
  - Brief the ACRS after public comment
  - Finalize in Spring 07

NUREG-1852—Approach

- Deterministic criteria developed on the basis of
  - Existing Inspection guidance, insights and experience developed through the years of inspecting manual actions currently used by licensees in response to fire
  - Human factors guidance documents and standards addressing human actions in general and in response to fire in particular (e.g., SRP Chapter 18.0, "Human Factors Engineering", Info. Notice 97-78, and the ANS/ANSI 58.8 standard)
  - Review of findings/insights from plant updated PRAs, IPEEE reports, Fire Re-Quantification project, and from HRA development and applications
    - In many respects, the criteria documented in NUREG-1852 are/were implicitly used by staff in review and inspection activities—now are explicitly documented
- Risk–informed approach to support review of risk-informed submittals (NFPA 805) will be developed in collaboration with EPRI—to be initiated in early 07

NUREG-1852— Overview

- Criteria for both feasibility and reliability of the actions
- Two parts:
  - Documentation of the criteria along with the technical basis
  - Guidance for implementing the criteria
- Essentially the same as that contained in DG-1136
- Difference:
  - No specific time margin is recommended in NUREG-1852
    - A factor of 2 was recommended in DG-1136
  - Demonstrating that "extra" time needs to be available to cover variability/uncertainty in fire conditions and manual action time is still emphasized and discussed
  - Licensees can justify their approach for addressing variability and uncertainties
- The change was done as result of public comments and Commission direction (SRM on SECY-04-0233, 1/18/05)
- NOTE: The ACRS was briefed in detail on these criteria, Nov 4, 2004.

NUREG-1852— Overview of the Criteria

- Adequate time available to ensure feasibility and reliability
- Environmental factors
- Equipment functionality and accessibility
- Availability of indications
- Communications
- Portable equipment
- Personnel protection equipment
- Procedures, training and staffing
- Demonstrations of the credited human actions

Feasibility

- An action can be considered feasible if it can be shown that it can be accomplished within the “estimated” available time
- Guidance
  - An estimate of the time available is performed through analyses
  - Unique fire related uncertainties are taken into consideration in the estimation of the time available
  - An estimate of the time to diagnose the need for the action and implement it should be done on the basis of walkdowns, talkthroughs, judgment, and substantiated thru demonstrations
  - A comparison of the “estimated” time and the time identified as needed to successfully diagnose and perform an action shows that adequate time is available, OR
  - If "conservative" estimations of the time available is performed, justify that the conservative assumptions are adequate to "make-up" the additional time needed to cover the demonstrated time required

Reliability

- A feasible action is reliable if it can be shown that the estimated available time envelops the various sources of uncertainties
  - problems with equipment, e.g., locked doors
  - environmental effects, e.g., smoke and toxic gas
  - different travel paths
  - variability among crews
  - conditions/actions impractical or impossible to demonstrate
- Guidance
  - Justify that conservatism in time estimations envelops the additional uncertainties for both diagnosing and performing an action
  - Show that an adequate "time margin" exists for applicable uncertainties in addition to the time required for the action as measured in the demonstration
  - Justify any other approach employed to address reliability
  - NOTE: The "time margin" serves as a surrogate measure to account for the uncertainties typically considered in a PRA/HRA.

Environmental Factors

- Environmental factors are conditions that could negatively impact the ability to perform the manual actions, e.g.,
  - Radiation, lighting, temperature, smoke, toxic gas
- Guidance: Environmental factors should be shown to be consistent with established human factors considerations, e.g.,
  - Lighting should be provided per regulations and the fire protection program
  - Radiation should not exceed the 10CFR20.1201 limits
  - Temperature and humidity should not prevent successful performance
  - Smoke and gas should not impair accessibility or hinder successful performance

Equipment Functionality and Accessibility

- Equipment necessary to achieve and maintain post-fire hot shutdown is accessible, available, and not damaged or otherwise adversely affected by the fire and its effects (e.g., heat, smoke, and water)
- Guidance: In crediting functionality of equipment, consider the unique fire effects that may render the equipment inoperable
  - Generally no credit for actions and equipment involving the use or manipulation of equipment in areas that could be exposed to the fire effects
  - "Functionality of equipment" must be ensured
  - Knowledgeable personnel should have access to all necessary equipment

Availability of Indications

- Indications should be available to (1) support diagnosis of the need for an action, (2) determine which actions are appropriate, and (3) provide feedback to the operators
- Guidance: Available indications should be sufficient to successfully accomplish tasks (1), (2), and (3)
  - Indicating instruments should be functional and accessible according to "Functionality and Accessibility" criterion, either in the control room or locally
  - Compensatory measures should be provided for areas where no alarms or other compelling signals are available
  - Indications should be sufficiently redundant
  - Indications should be maintained as functional

Communications

- Equipment for effective communications should be available and meet the functionality and accessibility criterion
- Guidance: It should be shown that
  - Potential fire will not damage or disable communications equipment and/or personnel ability to successfully use the equipment given factors such as wearing protective clothing
  - Communications will work under environmentally challenging conditions such as extreme moisture
  - Personnel have substantial training on activities involving communication
  - Communication while wearing SCBAs, if necessary, can be successfully accomplished

Portable Equipment & Personnel Protection Equipment

- Portable equipment, especially unique tools (e.g., keys, flashlights, ladders) should be readily available and their location should be known and constant
- Personnel protection equipment such as protective clothing, gloves, and SCBAs should be available and access should be unimpeded so that it will not delay performing the actions
- Guidance
  - Equipment readily available and controlled
  - Personnel should be trained in the use of the equipment
  - Use of the equipment should be considered in the manual action time especially if it will have an effect of slowing down the time to implement the action

"Procedures and Training" & Staffing

- Written plant procedures should be maintained that cover all the manual actions that each operator might be required to perform; plant training program should ensure that these operators receive training in these procedures
  - Procedures should be maintained current and reflect actual plant configuration
- Adequate numbers of qualified personnel should be on site at all times so that shutdown conditions can be achieved and maintained in the event of a fire
  - Essential individuals should not have collateral duties, i.e., all operating staffing levels should have enough people to perform any manual actions that could be needed since a fire could occur at any time

Demonstrations

- Demonstrate, by at least one randomly-selected established crew, that the credited operator manual actions are both feasible and reliable
  - Ensure that credited actions are achievable within the constraints, including available time
  - Show adequate time exists to ensure reliability, i.e., extra time exists to account for factors not covered in the demonstration and inherent variability/uncertainty
  - Demonstrate capability to handle complexities such as diagnosis to perform actions, number of actions needed, dependence of one-action-to-another, and handling of multiple procedures at the same time
- Guidance
  - Plant staff should not rely on manual actions until it is demonstrated that they can be performed consistent with the analysis
  - Demonstrations should be as realistic as possible
  - Subsequent "full-blown" demonstrations may not be necessary

NUREG-1852--Summary

- NUREG-1852 establishes criteria to support NRC reviews of licensee requests to use manual actions to maintain safe shutdown after a fire event
- Was created by building-on and documenting existing NRC guidance and practices
- Addresses both feasibility and reliability
- Will be revised after public comment
- Will brief the ACRS on comments received and how were addressed
- To be published by April 2007

NUREG-1852 "DEMONSTRATING THE FEASIBILITY AND RELIABILITY OF OPERATOR MANUAL ACTIONS IN RESPONSE TO FIRE"

Plan for Use by the Office of Nuclear Reactor Regulation

Sunil Weerakkody, Ph. D.
Chief, Fire Protection Branch
NRR

KEY REGULATORY DOCUMENTS

- 10 CFR 50.48: "Fire Protection"
- Regulatory Issue Summary (RIS) 2006-10: "Regulatory Expectations with App. R, ¶ III.G.2, Operator Manual Actions (OMAs)"
- Standard Review Plan (NUREG-0800), §9.5.1: "Fire Protection Program (FPP)"

SUPPORTING GUIDANCE DOCUMENTS

- Regulatory Guide (RG) 1.189: "FP for NPPs"
- Criteria for inspectors: NRC Inspection Procedure 71111.05, "FP"
- NUREG-1852: OMA feasibility and reliability criteria for NRR staff use when reviewing future license amendments and exemption requests

RG 1.189: DETECTION & SUPPRESSION

- "Use of NUREG-1852 <u>does not</u> obviate [fire] detection and automatic suppression required by the regulations"
  - "Omission or elimination of detection or automatic suppression required by regulations in an area containing systems, structure and components (including circuits) important to safety would generally be considered an adverse effect on safe shutdown since it would reduce, at a minimum, FP defense-in-depth"

RG. 1.189: TIME MARGIN

- Replacing FP systems or features with OMAs is typically unacceptable if redundant divisions required for safe shutdown are located in the same fire area, unless alternative/dedicated shutdown capability is provided
- Using OMAs for alternative/dedicated shutdown capability should ensure that the time period to perform them is not critical to plant safety
  - This implies the need for some degree of "time margin" to account for potential uncertainties that can arise from human action variability or the random nature of fires themselves

NRR USE OF NUREG-1852

- Unless the exemption request or potential inspection finding cites an alternative approach to evaluating the feasibility and reliability of the OMAs, the NRR staff will perform its technical evaluation using the bases and guidance in NUREG-1852
  - Risk-informed/performance-based evaluations for OMAs <u>may</u> use NUREG-1852 where qualitative insight is needed

NUREG-1852 LIMITATIONS

- Feasibility and reliability criteria in NUREG-1852 are not intended to apply to actions taken during Main Control Room abandonment due to fire
  - Addressed in GL 86 10 question and answer 3.8.4
- NUREG-1852 does not establish defense-in-depth criteria for substituting manual actions in lieu of fire protection regulatory requirements, such as those in App. R, paragraph III.G.2
  - Purview of SRP §9.5.1, RG 1.189, RIS 2006 01

NIST

EPRI

SAIC Science Applications International Corporation

VERIFICATION AND VALIDATION OF SELECTED FIRE MODELS FOR NUCLEAR POWER PLANT APPLICATIONS: ENGINEERING (HAND CALCULATIONS)— FDT^S & FIVE-REV1

Jason Dreisbach, NRC-RES
Francisco Joglar, SAIC

ACRS Reliability and PRA Subcommittee
September 21, 2006
Rockville, MD

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES), Electric Power Research Institute (EPRI), and the National Institute of Standards and Technology (NIST)

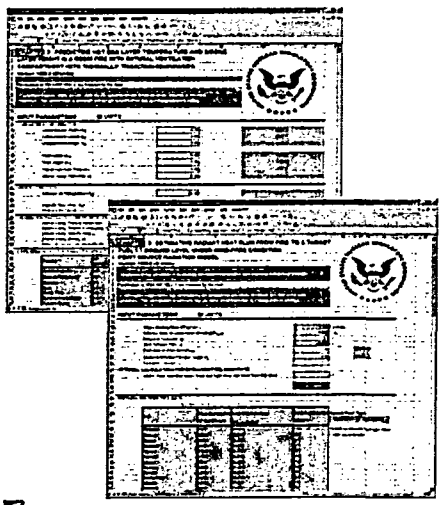
Engineering (Hand) Calculations

- Hand calculations are essential for a risk informed environment
- Experience in the field conducting
  - Fire Protection Significant Determination Processes (SDP)
  - Fire PRA's
  - License amendment requests

suggests that Hand Calculations are efficient and effective tools for most hazard calculations

- Fire modeling calculations can be conducted quickly
  - This allows fire risk analyses to provide relevant insights within budget and schedule

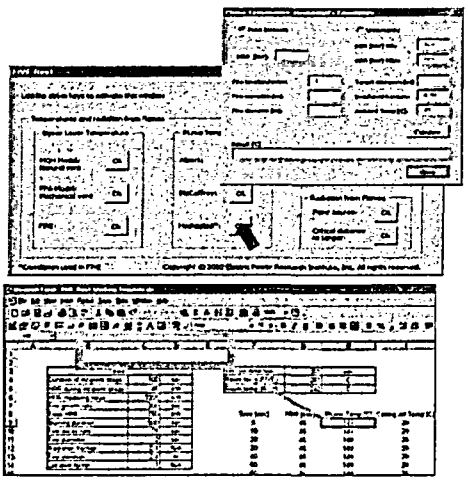
FDTs



- Compiled and documented by the NRC
- FDTs are a series of Microsoft Excel® spreadsheets issued with NUREG-1805, "Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program."
- The primary goal of FDTs was to be a training tool to teach NRC Fire Protection Inspectors an Introduction to Fire Dynamics.
- The secondary goal of FDTs was to be used in plant inspections and support other programs that required Fire Dynamics knowledge such as, Significance Determination Process (SDP) and NFPA 805.

FIVE-Rev1

- Compiled and documented by EPRI (EPRI 1002981)
- More than ten years after FIVE, most of the equations are still considered "State-of-the-Art"
- Models are compiled in a Microsoft Excel spreadsheet
- Graphical interface & takes advantage of the Excel spreadsheet environment

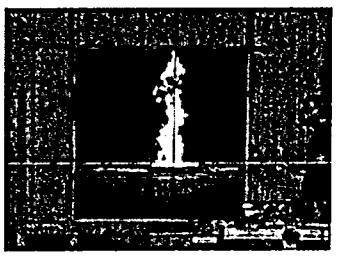


V&V Models

Fire Modeling Parameter	FDT[s]	FIVE-Rev1
1. Hot gas layer temperature	MQH, FPA, Beyler, Beyler & Deal	MQH, FPA
2. Hot gas layer height	Yamana & Tanaka	No model
3. Ceiling jet temperature	No model	Alpert's ceiling jet temperature
4. Plume temperature	Heskestad's plume temperature	Heskestad's plume temperature
5. Flame height	Heskestad's flame height	Heskestad's flame height
6. Radiated heat flux to targets	Point source flame radiation model, Solid flame model	Point source

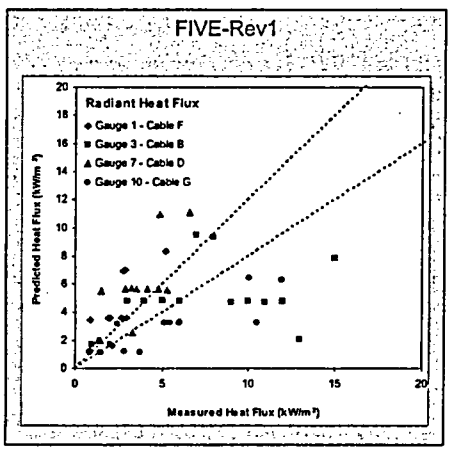
- No models are available or were validated for surface temperature, room pressure, Oxygen or smoke concentration and total heat flux

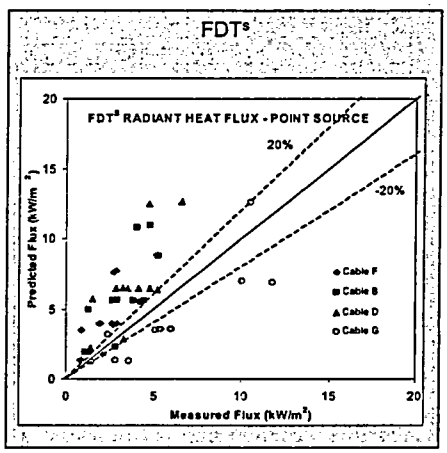
Selected Results: Flame Height



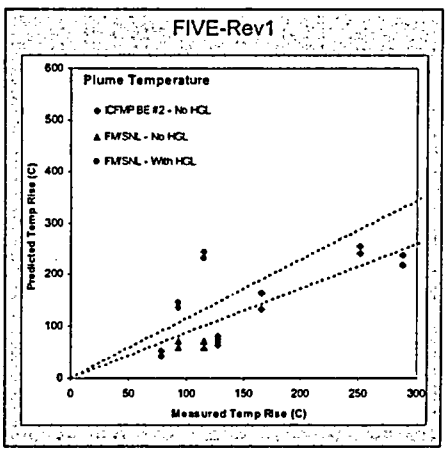
- Conclusions based on comparisons with pictures and videos of the experiments
- Predictions are consistent with visual observations of flame height in the experiments

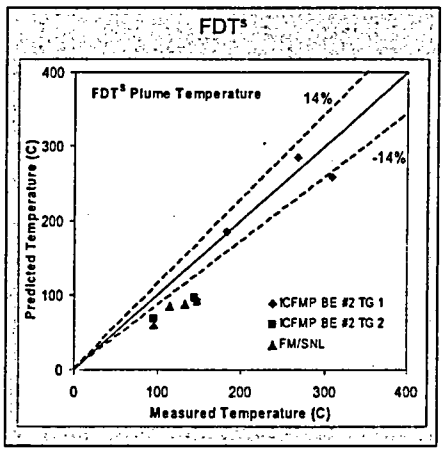
Selected Results: Flame Radiation



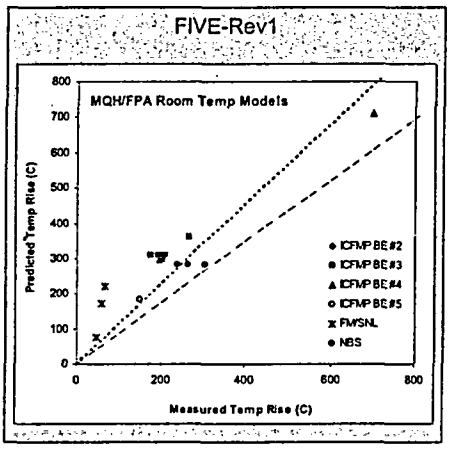


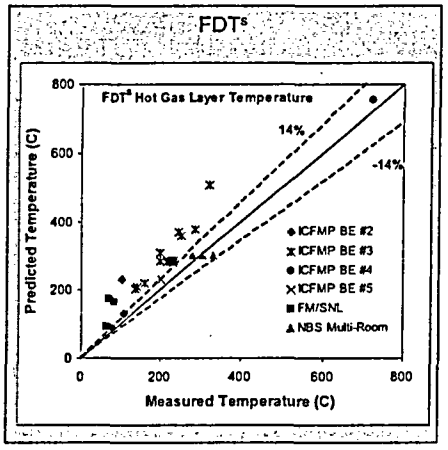
Selected Results: Plume Temperature





Selected Results: Hot Gas Layer Temperature





Closing Remarks

- Hand calculations are essential tools for fire hazard and fire risk analysis in NPP applications
- Hand calculations can address a number of the modeling needs in NPP applications
- Results of the V&V analysis confirms the importance of understanding the capabilities and limitation of each model when used for analyzing fire scenarios

NIST

EPRI

SAIC Science Applications International Corporation

VERIFICATION AND VALIDATION OF SELECTED FIRE MODELS FOR NUCLEAR POWER PLANT APPLICATIONS: ZONE MODELS—CFAST & MAGIC

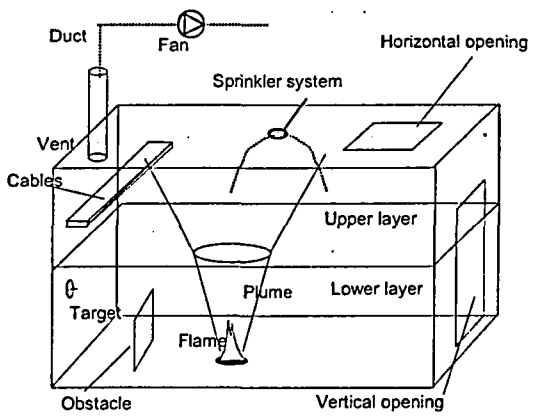
Rick Peacock, NIST
Francisco Joglar, SAIC

ACRS Reliability and PRA Subcommittee
September 21, 2006
Rockville, MD

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES), Electric Power Research Institute (EPRI), and the National Institute of Standards and Technology (NIST)

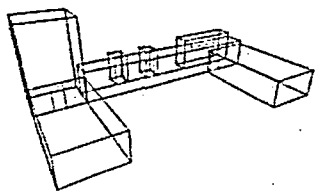
Two Zone Models

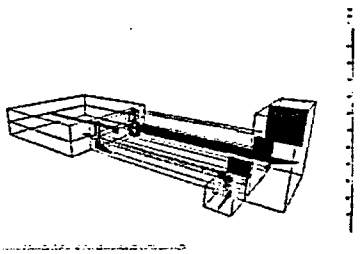
- A rectangular room is divided into 2 control volumes where conservation equations for mass and energy are solved resulting in room pressure, and layer temperatures
- Compartments are connected with vertical, horizontal, or mechanical ventilation openings.



CFAST

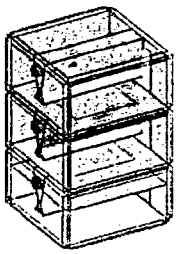
- Developed by NIST
- Latest version released in 2006
- Widely used and available general purpose zone fire model
- User friendly interface; Visualization in Smokeview

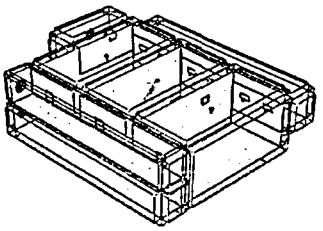


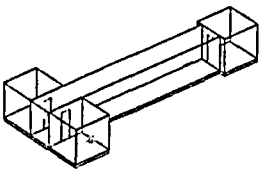


MAGIC

- Developed by EDF
- Latest version released in 2006; Incorporated lessons learned from the V&V process
- Available only from EPRI but includes features specific to NPPs
- User friendly interface



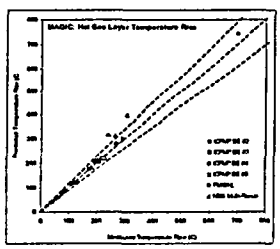


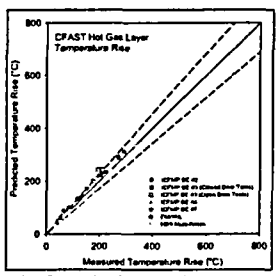


General Capabilities Evaluated in the V&V

- Hot gas layer temperature and height
- Ceiling jet temperature
- Plume temperature
- Flame height
- Room pressure
- Oxygen & smoke concentration
- Radiant and total heat flux to targets and walls
- Target & wall temperature
- Multi-compartment analysis

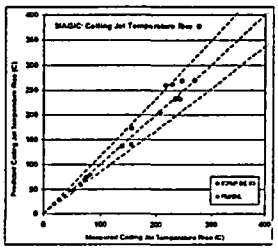
Selected Results: Hot Gas Layer Temperature

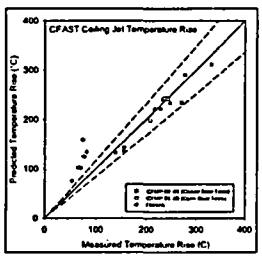




- MAGIC and CFAST predictions of HGL temperature and height are appropriate for the intended application.
- Predictions are, with few exceptions, within or close to experimental uncertainty.
- Calculation of HGL temperature and height show higher uncertainty in rooms remote from the fire.

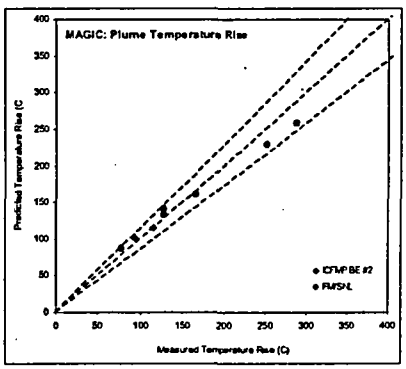
Selected Results: Ceiling Jet Temperature





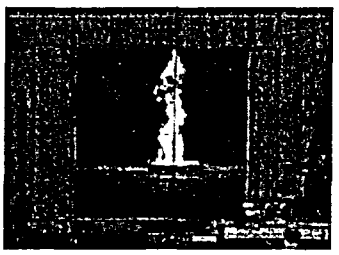
- Both based on Cooper's ceiling jet model
- With exceptions, MAGIC predicts temperatures within experimental uncertainty.
- CFAST predicts well within experimental uncertainty for cases with a clearly developed ceiling jet; less well for lower temperatures

Selected Results: Plume Temperature



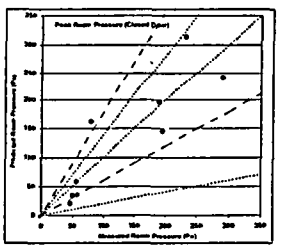
- CFAST does not directly calculate or report plume temperature
- For MAGIC, all values are within experimental uncertainty

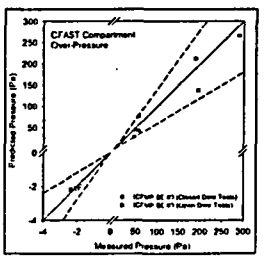
Selected Results: Flame Height



- Conclusions based on comparisons with pictures and videos of the experiments
- Predictions are consistent with visual observations of flame height in the experiments

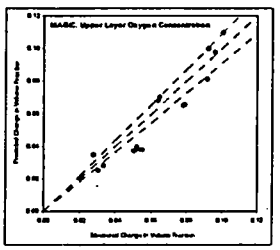
Selected Results: Room Pressure

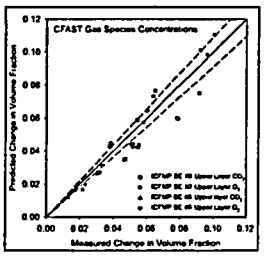




- Predictions of room pressure for open-door tests are within experimental uncertainty
- Predictions of room pressure for closed door tests are naturally sensitive to leakage and mechanical ventilation; most values within experimental uncertainty

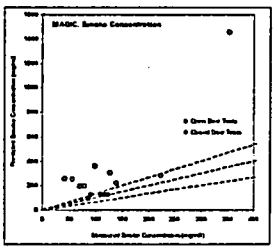
Selected Results: Oxygen Concentration

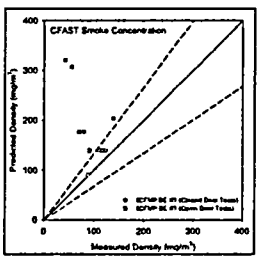




- MAGIC predicts oxygen concentration with experimental uncertainty for closed door tests and under predicts for open door tests
- CFAST predictions similar to MAGIC for oxygen and close to experimental uncertainty for CO_2

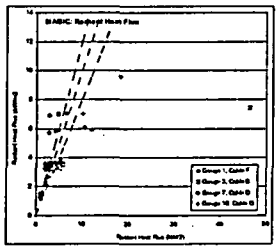
Selected Results: Smoke Concentration

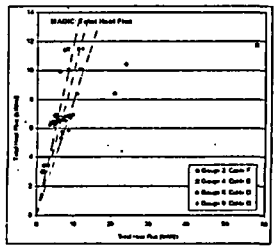


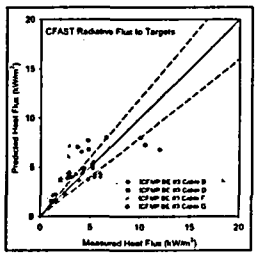


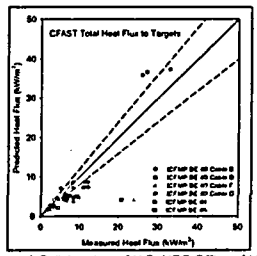
- Both models typically over predict smoke concentration
  - Open door tests within or close to experimental uncertainty
  - Closed door tests significantly over predicted due to either experimental measurement or changing smoke yield in close door tests

Selected Results: Heat Flux

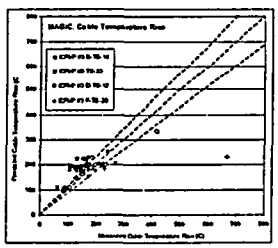


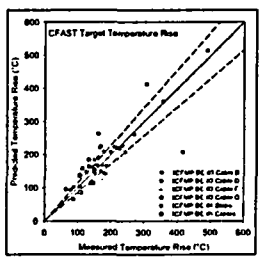






Selected Results: Target Temperature





- Target temperatures often within experimental uncertainty, with exceptions for particular cable geometries
- Temperature predictions reflects accuracy of heat flux predictions and limitations of zone modeling (over predictions in far-field and under predictions in near field)

Closing Remarks

- Zone models provide appropriate prediction of quantities of interest for NPP applications
- Zone model predictions of HGL temperature, HGL height, ceiling jet temperature, plume temperature, flame height, and room pressure are typically well within experimental uncertainty
- Zone model predictions of gas concentration, smoke concentration, target flux, and target temperature require care and an understanding of the capabilities and limitation of zone models when used for analyzing fire scenarios

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VERIFICATION AND VALIDATION OF SELECTED FIRE MODELS FOR NUCLEAR POWER PLANT APPLICATIONS: CFD MODEL—FDS

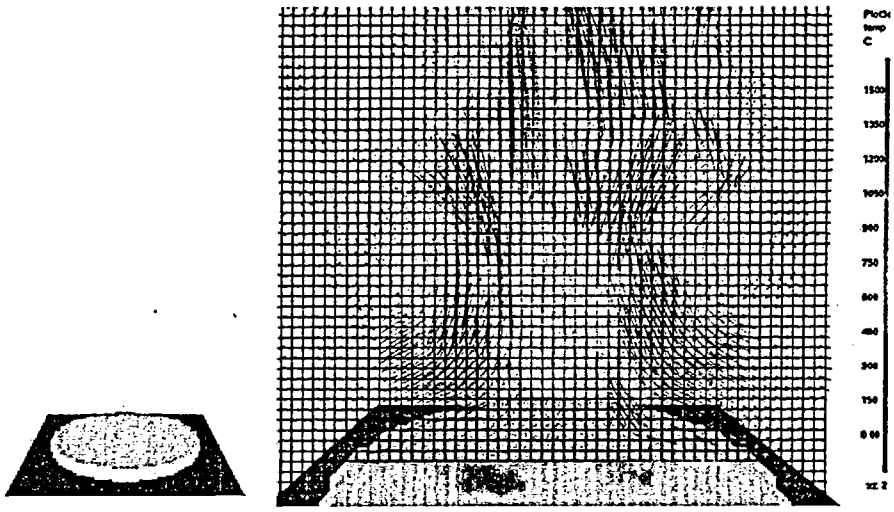
Kevin McGrattan, NIST

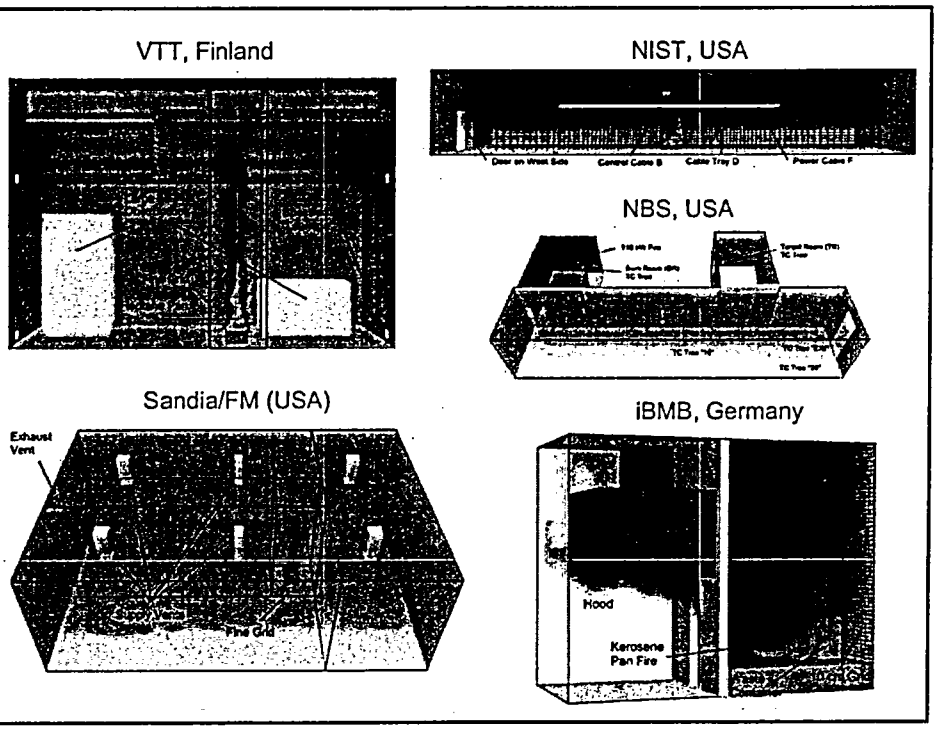
ACRS Reliability and PRA Subcommittee
September 21, 2006
Rockville, MD

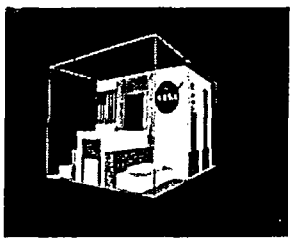
A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES), Electric Power Research Institute (EPRI), and the National Institute of Standards and Technology (NIST)

What is the Fire Dynamics Simulator (FDS)?

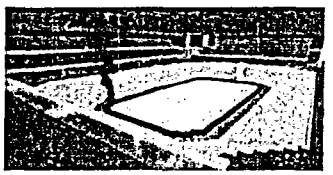
- Computational fluid dynamics (CFD) model of fire driven fluid flow
- Designed specifically to study fire dynamics
- Low Mach Number approximation for thermally driven flows
- Large Eddy Simulation (LES) turbulence model
- Relatively simple numerical grids
- Commonly used by the fire protection engineering community



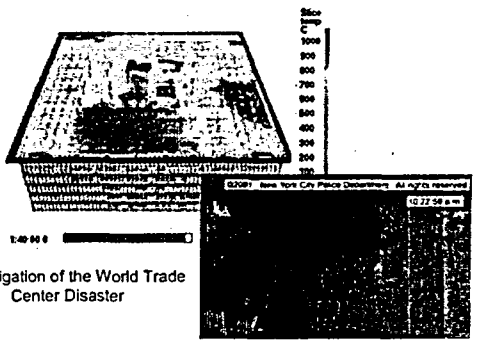

VTT, Finland
NIST, USA
NBS, USA
Sandia/FM (USA)
Exhaust Vent
Fire Grid
iBMB, Germany
Hood
Kerosene Pan Fire



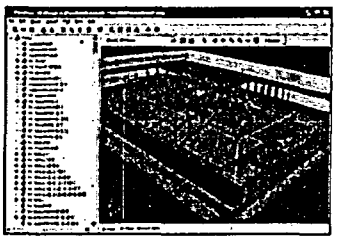
NASA Vehicle Assembly Building
Kennedy Space Center
courtesy Rolf Jensen



2006 Olympic Ice Hockey Stadium,
Turin, Italy, courtesy Arup

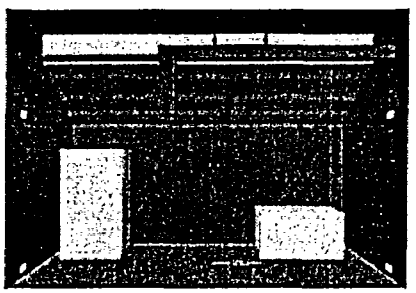


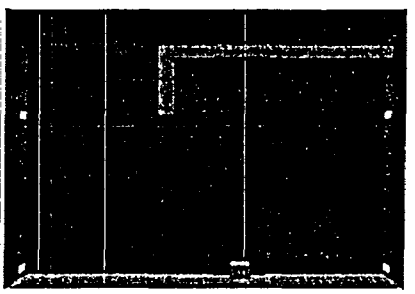
NIST Investigation of the World Trade
Center Disaster



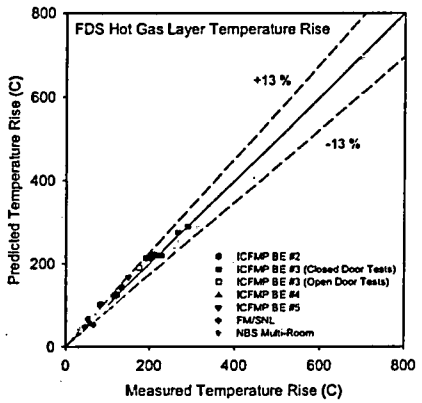
PyroSim, courtesy Thunderhead
Engineering Consultants, Manhattan, Kansas

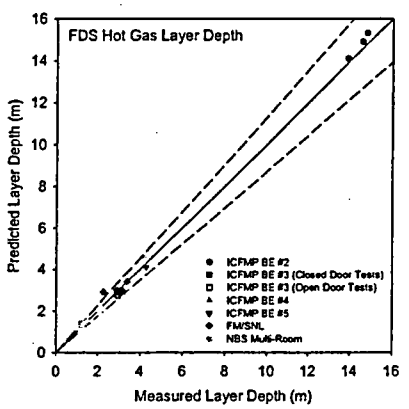
Example – Smoke Movement in Large Hall



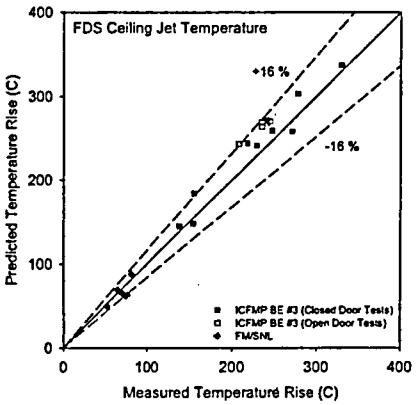


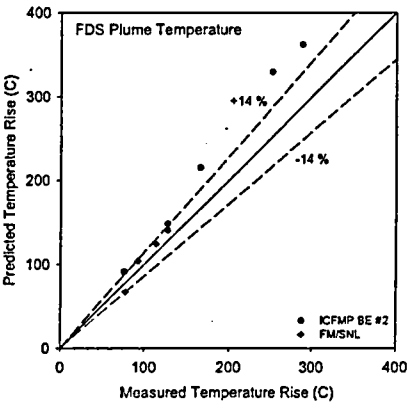
Hot Gas Layer Temperature and Depth



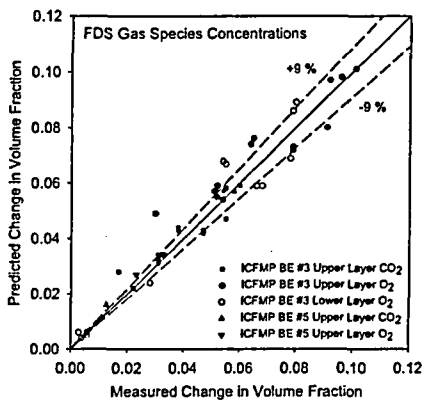


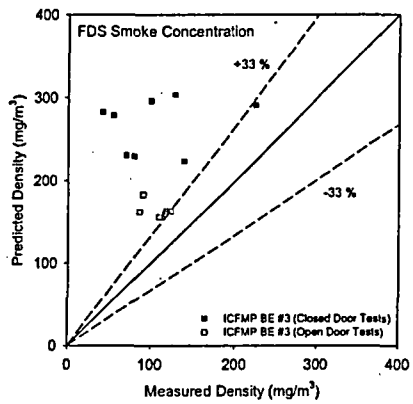
Ceiling Jet and Plume Temperature



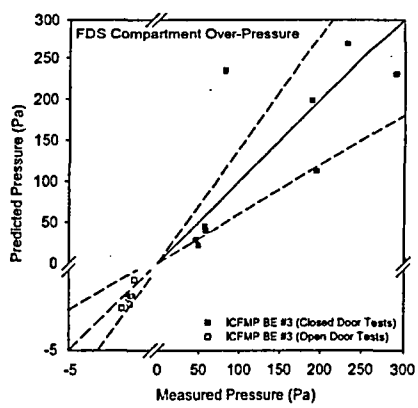


Gas Species and Smoke Concentration

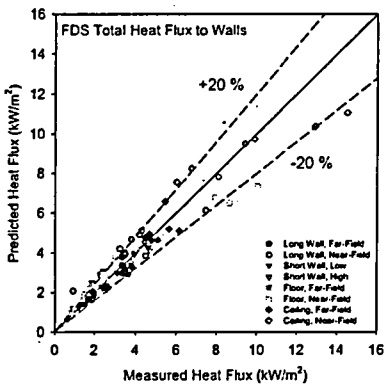


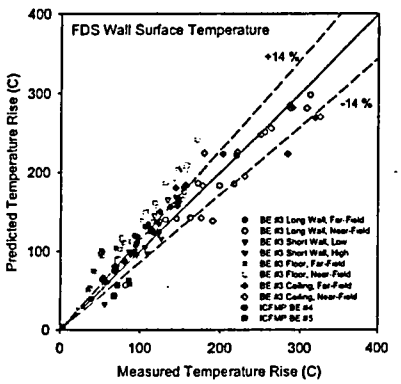


Compartment Over-Pressure

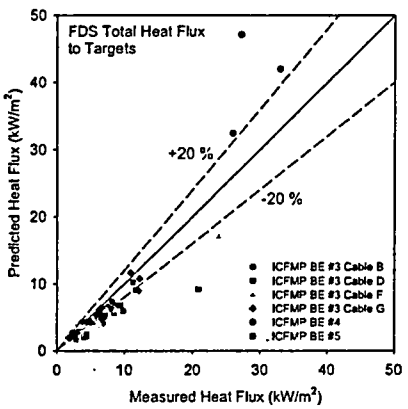


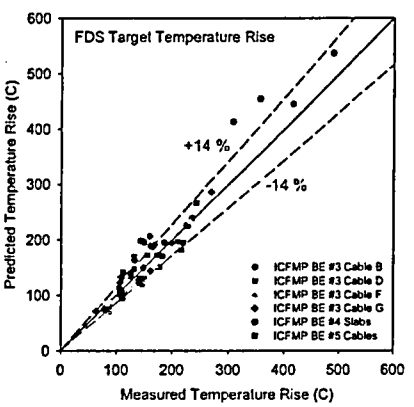
Heat Flux and Wall Temperature





Heat Flux and Target Temperature





Conclusion

- FDS evaluated as part of NRC/EPRI V&V study
- In general, the experiments conformed to the classic 2 layer fire model
- CFD model only marginally more accurate, even though it demands about 1000 times the CPU time (minutes vs days)
- CFD is very powerful, but may be unnecessary for design fire applications in non-cluttered compartments with flat ceilings
- Obstructions/geometric complexity should impact selection of model type

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VERIFICATION & VALIDATION OF SELECTED FIRE MODELS FOR NUCLEAR POWER PLANT APPLICATIONS: SUMMARY RESULTS

ACRS Reliability and PRA Subcommittee
September 21, 2006
Rockville, MD

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES), Electric Power Research Institute (EPRI), and the National Institute of Standards and Technology (NIST)

User's needs

Step 1:
Define fire modeling objectives

Step 2:
Select and describe fire scenario(s)

Step 3:
Select appropriate fire model(s)

Step 4:
Estimate fire-generated conditions

Step 5:
Interpret and use results

- Quantitative validation provides information to help select the appropriate fire models for the specific scenario (Step 3)
- Quantitative validation gives user a level of confidence in the results of the models (Step 5)

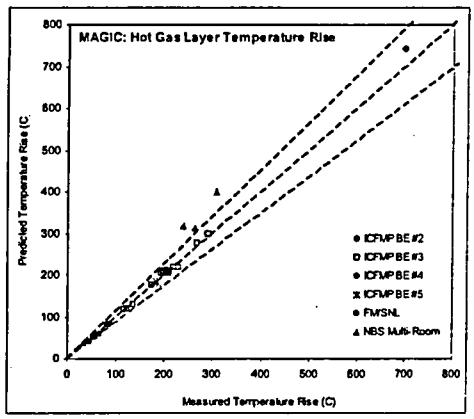
Characterizing the Results

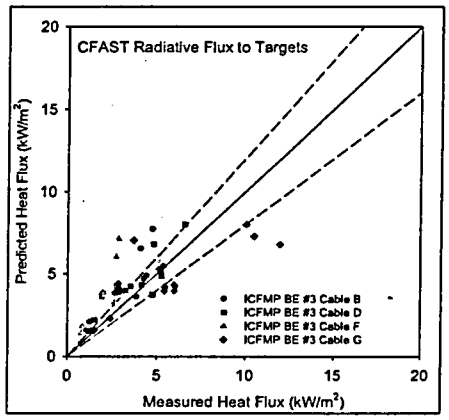
- GREEN
  - Physics are appropriate
  - Model predicts close to and/or within uncertainty
  - Physics are appropriate
  - Sometimes model predictions are outside of uncertainty
- RED
  - Physics are not appropriate
- "N/A": not applicable
  - Sub-model for this calculation not included in model

Table of Results

Parameter [1]		Fire Model				
		FDT [2]	FIVE - Rev 1	CFAST	MAGIC	FDS
Hot gas layer temperature (" Upper Layer Temperature ")	Room of Origin	YELLOW+	YELLOW+	GREEN	GREEN	GREEN
	Adjacent Room	N/A	N/A	YELLOW	YELLOW+	GREEN
Hot gas layer height (" Layer interface height ")		N/A	N/A	GREEN	GREEN	GREEN
Ceiling jet temperature (" Target/Gas temperature ")		N/A	YELLOW+ [3]	YELLOW+	GREEN	GREEN
Plume temperature		YELLOW –	YELLOW+ [3]	N/A	GREEN	YELLOW
Flame height [1]		GREEN	GREEN	GREEN	GREEN	YELLOW [4]
Oxygen concentration		N/A	N/A	YELLOW	YELLOW	GREEN
Smoke concentration		N/A	N/A	YELLOW	YELLOW	YELLOW
Room pressure [1]		N/A	N/A	GREEN	GREEN	GREEN
Target temperature		N/A	N/A	YELLOW	YELLOW	YELLOW
Radiant heat flux		YELLOW	YELLOW	YELLOW	YELLOW	YELLOW
Total heat flux		N/A	N/A	YELLOW	YELLOW	YELLOW
Wall temperature		N/A	N/A	YELLOW	YELLOW	YELLOW
Total heat flux to walls		N/A	N/A	YELLOW	YELLOW	YELLOW

GREEN vs. YELLOW





Conclusions

- For most of the widely used attributes in NPP fire modeling model predictions are either GREEN or YELLOW+
  - Plume temperature, ceiling jet temperature, HGL temperature, flame height
- Exceptions are:
  - Radiant heat flux
    - Scenarios involving fire damage to adjacent targets, e.g., a relay room
  - Smoke concentration
    - Main control room habitability and control room evacuation scenarios
    - Sensitivity
  - Target temperature
    - For example, when estimating timing of damage to cables

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SAIC Science Applications International Corporation

VERIFICATION & VALIDATION OF SELECTED FIRE MODELS FOR NUCLEAR POWER PLANT APPLICATIONS: PROGRAMMATIC OVERVIEW AND TECHNICAL APPROACH

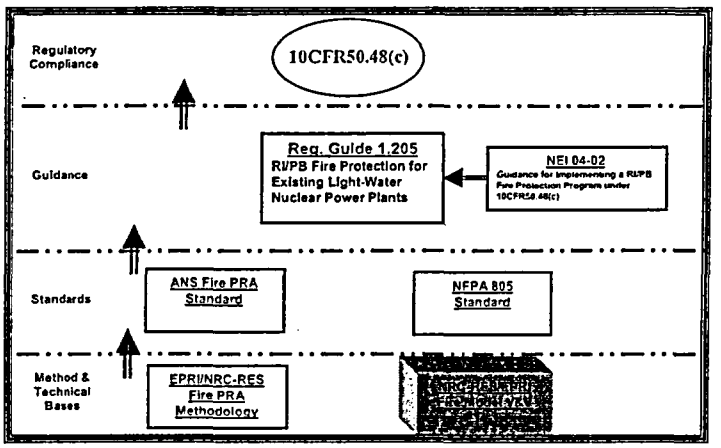
ACRS Fire Protection Subcommittee
September 21, 2006
Rockville, MD

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES), Electric Power Research Institute (EPRI), and the National Institute of Standards and Technology (NIST)

Background

- Use of fire models is becoming increasingly important in risk-informed, performance informed regulatory environment
  - Under NFPA 805 Section 2.4.1.2 (10CFR50.48(c))
    - "The fire models shall be verified and validated.
    - "Only fire models that are acceptable to the authority having jurisdiction shall be used..." ..."
    - "Fire models shall only be applied within the limitations of that Fire models shall only be applied within the limitations of that fire model."
  - Significance Determination Process
  - Deviation/Exemption requests under existing fire protection rule
- Use of fire models in such environment requires understanding their predictive capabilities (quantitative where possible) for nuclear power plant fire scenarios

Regulatory Framework



Project Objectives

- Gain understanding of predictive capabilities of selected fire models
- Specifically,
  - Address issues specific to nuclear power plant fire scenarios
  - Characterize the predictive capability of these models to the extent that can be supported by experimental data and is useful in a RI/PB environment
  - Establish a process that can be used for other fire scenarios or models if necessary

Challenges

Fire Modeling and Science

1. Appropriateness of the model to the fire scenario

   Experience and perspective in model development to qualify/quantify confidence in model prediction

2. Appropriateness of the experiment to the fire scenario

   Experience and perspective with NPP fire modeling to qualify/quantify

Error Analysis

3. Performance of the model in predicting experimental outcomes

   Experience and perspective with NPP fire modeling to qualify/quantify

Statistical Method

4. And a method to combine these various elements

Project Team

- Our project team is aimed at fulfilling the challenges of such project
- Expertise in the critical skill sets
  - *NPP fire scenarios*: Understanding of the nuclear power plant fire scenarios, critical attributes and ranges of conditions [EPRI, NRC]
  - *Fire Science & model development*: Understanding of the physics and challenges the models face in representing NPP fire scenarios [NIST, EDF, EPRI, NRC]
  - *Fire Experiments*: Understanding of the challenges the experiments face in representing fire scenarios and model predictions [NIST]
- Independent review:
  - Prof. Jim Quintiere, University of MD
  - Dr. Craig Beyer & Mr. Phil DiNenno, Hughes & Associates

Public Comments

- Comments provided during public comment period by industry and consultants (322)
  - PG&E, ASTM, KEPRI (Korea), NYC Transit, Fluent Inc., Combustion Science & Engineering Inc.
- Comments provided by NRR (190)
- Minor changes and clarifications only
- Highlight specific changes throughout presentations

Presentations

- Technical Overview; Methodology
- Experimental Uncertainty
- Verification & Validation
  - Hand-calculations' FDTs and FIVE-Rev 1
  - Two-zone models' CFAST and MAGIC
  - Fire Dynamic Simulator (FDS)
- Summary of the project results

Technical Approach

- Verification - process to determine that a model correctly represents the developer's conceptual description—was the model "built" correctly?
- Validation - process to determine that a model is a suitable representation of the real world and is capable of reproducing phenomena of interest—was the correct model built?
- The V&V method must be transparent and reproducible

V&V for NPP Applications

- What fire scenarios are of concern?
- What are the important measurements/parameters?
- What experiments have been performed that will address these concerns?
- What models can be used?
- How do we evaluate the models?
- How do we know if a model is valid for specific circumstances?

ASTM E 1355

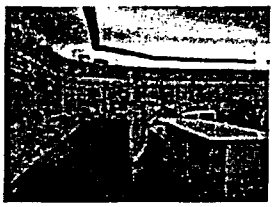
- A standard approach to address the questions
- Defines a process—the "hard work" is left to the model evaluator
  - Leaves it up to the evaluator (AHJ) to determine the "degree of accuracy required"
- Suggests approaches for validating, but does not require one over another

Fire Scenarios of Concern

- NPP fire scenarios represent
  - The demand (need) for fire modeling applications
  - The reality that needs to be modeled
- A library of NPP scenarios serves as the basis for a usable/practical V&V study
- Developed based on
  - Potential risk significant scenarios through review of IPEEE submittals
  - Review of range of possible NPP configurations
  - Examination of past industry experience in support of regulatory applications (other than IPEEE)
- Library of NPP scenarios suggested 13 fire modeling parameters for V&V

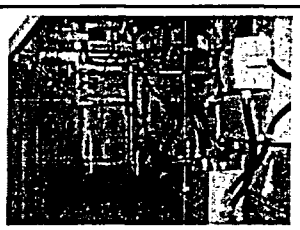
Important Measurements/ Parameters

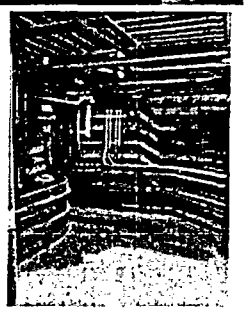
- Room Temperature
  - Main control room abandonment study
  - Targets in adjacent compartments
- Flame height, Plume & Ceiling jet temperature
  - Targets near the ignition source



Important Measurements/ Parameters

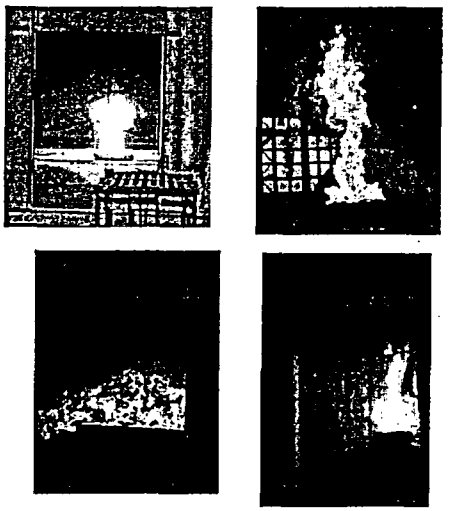
- Oxygen & Smoke concentration
  - Main control room habitability
- Room pressure
  - Issues related to mechanical ventilation
- Target/Wall heating and Target/Wall temperature
  - Most fire scenarios throughout the plant





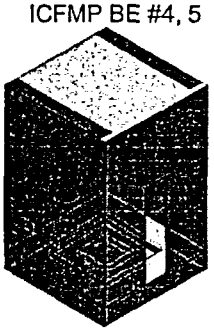
Experiments

- Considerations for selection
  - Quality data – instrumentation, knowledge of the HRR
  - *Well documented – important for* reproducibility of the V&V
  - Information about uncertainty
  - Support NPP applications
- International collaboration
- 26 experiments selected from 5 test series
  - ICFMP BE # 2, 3, 4, 5
  - FM/SNL
  - NBS



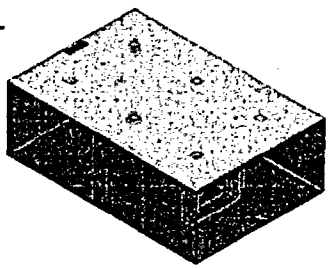
Pump Room

ICFMP BE #4, 5



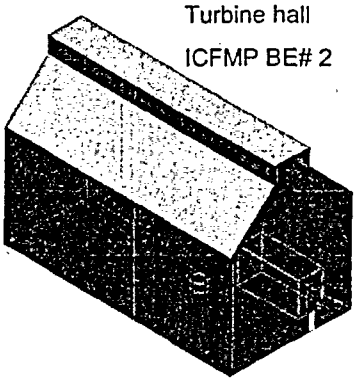
Main Control Room

FM/SNL



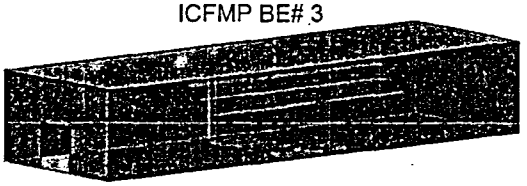
Turbine hall

ICFMP BE# 2



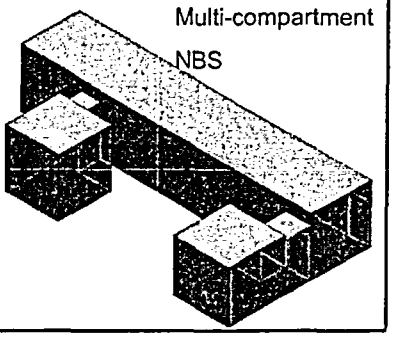
Misc.

ICFMP BE# 3



Multi-compartment

NBS



Models Selected

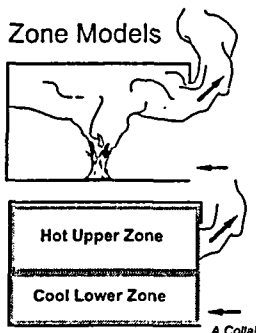
Fire Dynamics Tools (FDT^S)
FIVE-Rev1
Cons. Fire & Smoke Transport (CFAST)
MAGIC
Fire Dynamics Simulator (FDS)

NRC Spreadsheets
EPRI Spreadsheets
NIST zone model
Electricite de France zone
NIST CFD Model

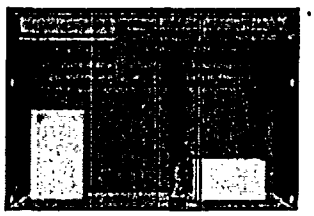
Spreadsheets

$$L_f = 0.23\dot{Q}^{2/5} - 1.02D$$

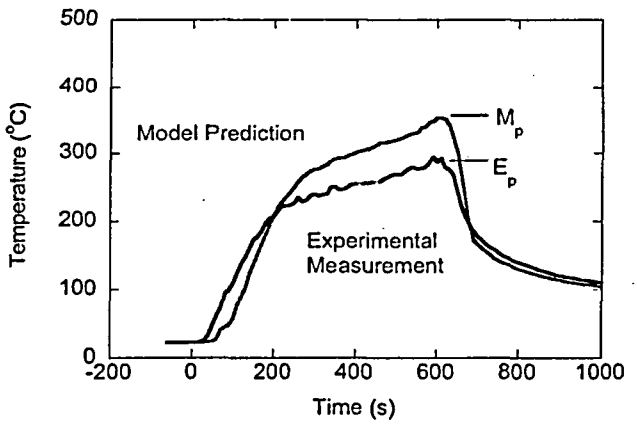
Zone Models



Field Models

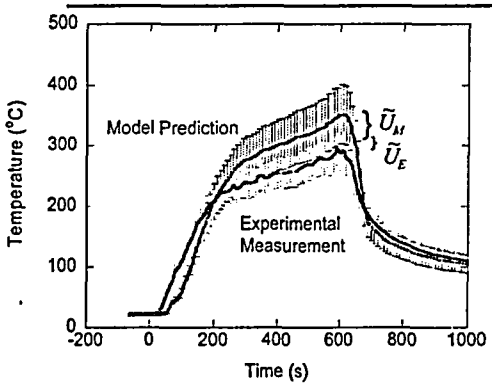


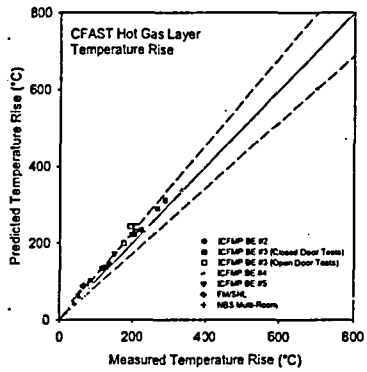
Traditional "Validation"



- "Model gives reasonably good prediction."

Validation using ASTM E 1355





- Simplification: Evaluate the peak values
- Use experimental uncertainty
- "Model predicts within experimental uncertainty."

Using the Results

- Scenarios can be described in terms of physical characteristics and phenomena of interest
- Translate physical characteristics and phenomena from real scenarios into "common language"
  - Normalized and/or non-dimensional parameters
- Compare with the range of parameters from experiments used in validation study

$$Q_d^* = \frac{\dot{Q}}{\rho_\infty c_p T_\infty \sqrt{gD}D^2} \qquad \phi = \frac{\dot{m}_F/\dot{m}_{O_2}}{r} = \frac{\dot{Q}/\Delta H_c/0.23\times\rho_{air}\dot{V}}{r}$$

$$D^* = \left(\frac{\dot{Q}}{\rho_\infty c_p T_\infty \sqrt{g}}\right)^{2/5}$$

Using the Results

- Compare with the range of parameters from experiments used in validation study

Parameter	ICFMP BE #2	ICFMP BE #3	ICFMP BE #4	ICFMP BE #5	FM/SNL	NBS Multi-Room	Validation Range
$\dot{Q}$ (kW)	1800 - 3600	400 - 2300	3500	400	500	100	N/A
$\dot{Q}_i$	≈ 1.0	0.4 - 2.1	2.4	0.7	0.6	1.4	0.4 – 2.4
ϕ Mechanical Ventilation	0.1	0.6	-	-	0.04 - 0.4	-	0.04 – 0.6
$D(m)$	1.17 - 1.60	1.00	1.13	0.79	0.91	0.34	N/A
$H(m)$	15.9	3.82	5.7	5.7	6.1	2.16	N/A
H/D	12 - 16	2.9 - 5.7	3.6	8.6	8.4	5.6	3.6 – 16

Coming Up Next

- Technical description of selected experiments
- Technical basis for uncertainty analysis
- Presentations on engineering calculations, zone models, and field model
- Results and Conclusions

NIST

EPRI

SAIC Science Applications International Corporation

VERIFICATION & VALIDATION OF SELECTED FIRE MODELS FOR NUCLEAR POWER PLANT APPLICATIONS: EXPERIMENTAL UNCERTAINTY

ACRS Reliability and PRA Subcommittee
September 21, 2006
Rockville, MD

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES), Electric Power Research Institute (EPRI), & the National Institute of Standards and Technology (NIST)

Experiments Selected

Six sets of experiments selected (26 tests in all)

Series	No. Tests	Fuels	$\dot{Q}$ (kW)	V (m^3)	H (m)
FM/SNL	3	Propylene	500	1400	6.1
NBS	3	Natural Gas/Acetylene	100	15	2.4
ICFMP BE #2	3	Heptane	1800-3600	5900	19
ICFMP BE #3	15	Heptane or Toluene	400-2300	580	3.8
ICFMP BE #4	1	Jet fuel	3500	74	5.7
ICFMP BE #5	1	Ethanol	400	73	5.6

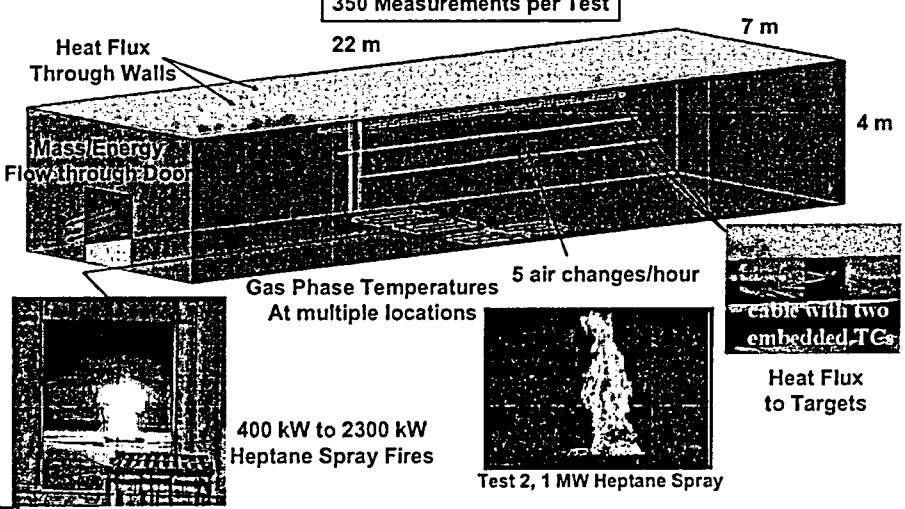
Experimental Uncertainty

- The test reports typically do not provide uncertainties for the individual measurements.
- Measurement uncertainty depends on the exact type of instrumentation, the experimental procedure, and the details of the measurement scenario.
- Uncertainties were based on previous experiments at NIST with similar instrumentation.

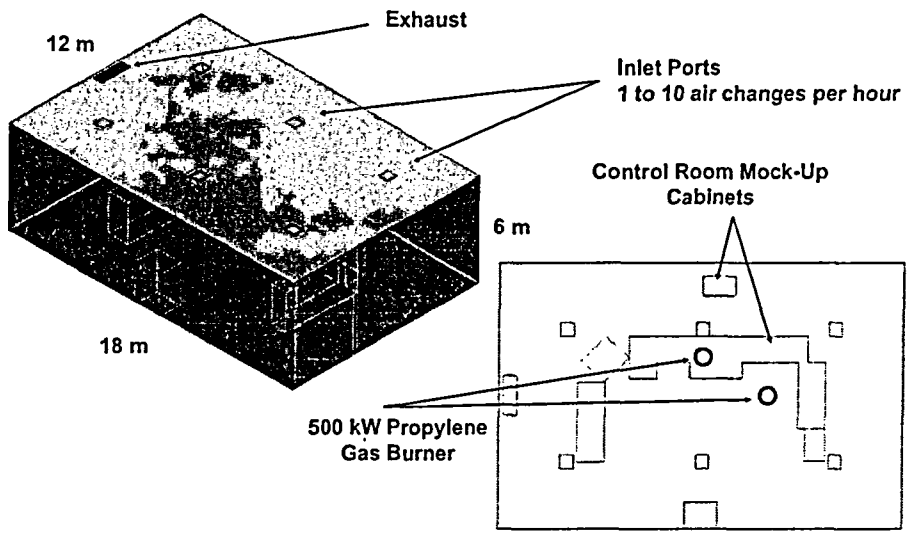
NIST/NRC Fire in a Switch Gear Room (2003)

ICFMP Benchmark Exercise #3

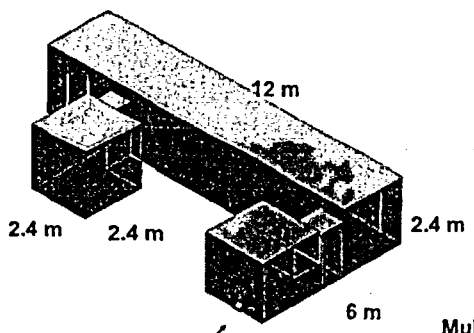
15 Tests
350 Measurements per Test



Factory Mutual / Sandia National Labs (1985)

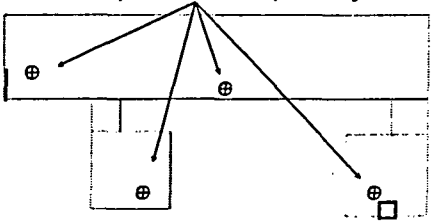


NBS Multi-Room Fire Tests (1985)



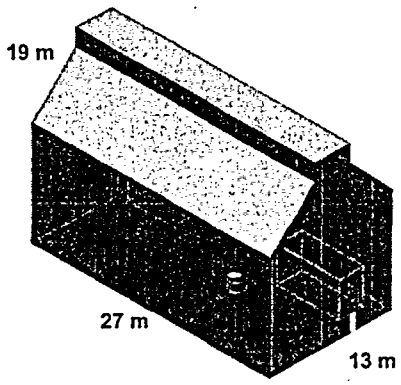
100 kW
Natural Gas

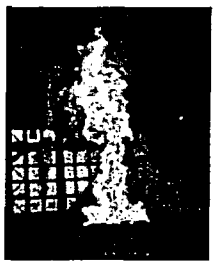
Multiple Thermocouple Arrays

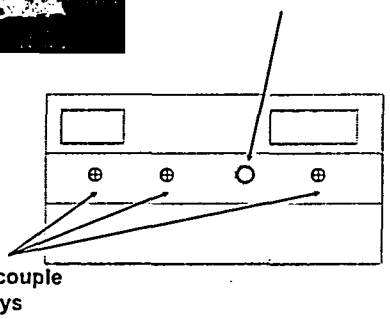


VTT (Finland) Large Hall Fire Tests (1998-1999)

ICFMP Benchmark Exercise #2



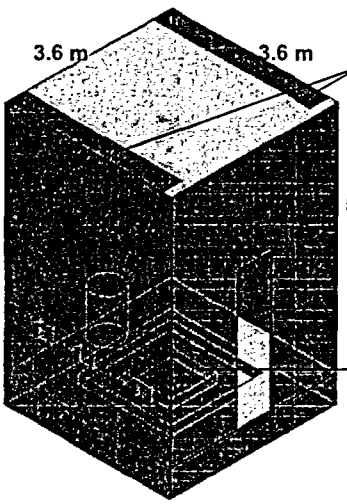


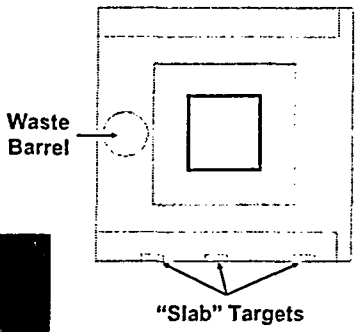


Institut für Baustoffe, Massivbau und Brandschutz (iBMB) Germany (2004)

Pool Fire Inside a Compartment

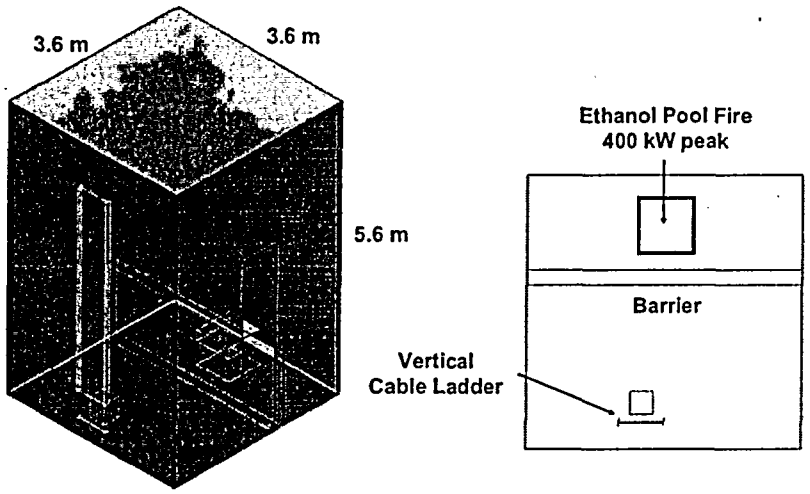
ICFMP Benchmark Exercise (BE) #4





3.5 MW
Jet Fuel Pool Fire

Institut für Baustoffe, Massivbau und Brandschutz (iBMB) Germany (2004)
Flame Spread in Cable Trays
ICFMP Benchmark Exercise #5



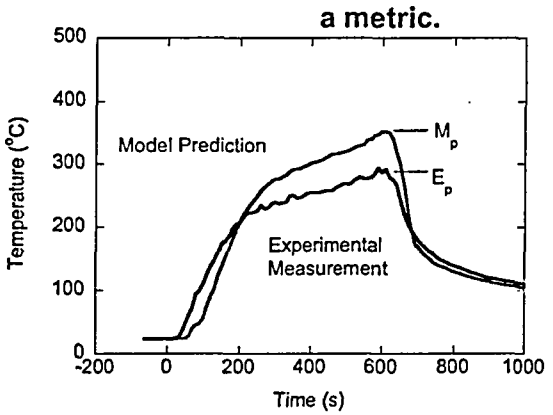
Parameters Predicted by the Models

1. Hot gas layer temperature
2. Hot gas layer height
3. Ceiling jet temperature
4. Plume temperature
5. Flame height
6. Oxygen concentration
7. Smoke concentration
8. Compartment pressure
9. Radiative heat flux to target
10. Total heat flux to target
11. Target temperature
12. Total heat flux to walls
13. Wall temperature

Comparison of Models with Actual Measurements

What is the degree of accuracy required by a predictive model? NFPA 805 and ASTM E 1355 don't say.

Proposed basis for comparison: **use experimental uncertainty as a metric.**

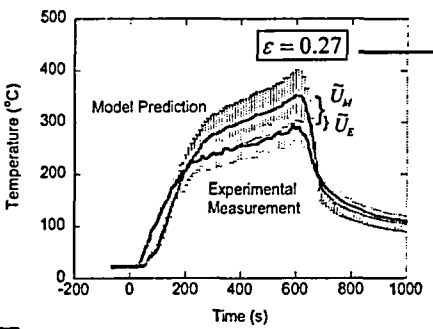


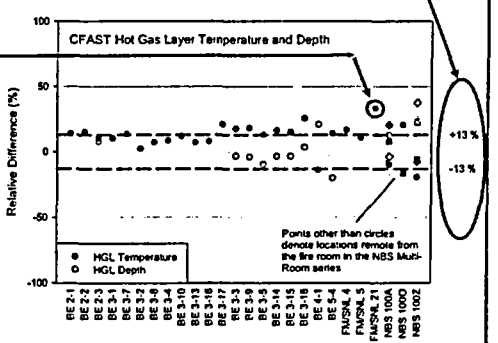
Model Evaluation Approach

$$\varepsilon = \frac{M_p - E_p}{E_p}$$ **Define relative difference**

$$U_C = \left(\tilde{U}_M^2 + \tilde{U}_E^2\right)^{1/2}$$ **Combined measurement & model uncertainties**

$$|\varepsilon| \overset{?}{<} U_C$$ **Assess**





Model Sensitivity to Uncertain Input

Experimental heat release rate, $\dot{Q}$, drives fire effects and its uncertainty dominates model sensitivity.

$$\dot{Q} = \chi_a \cdot \dot{m} \cdot H_c$$

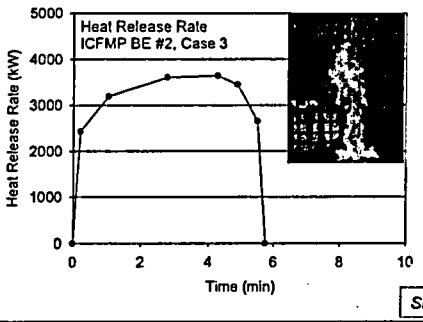
$\dot{Q} = heat\ release\ rate\ (kW)$

$\dot{m} = mass\ burning\ rate\ (g/s)$

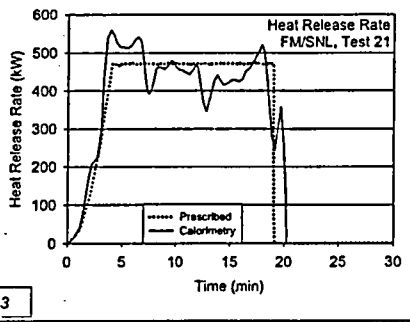
$\chi_a = combustion\ efficiency$

$H_c = heat\ of\ combustion\ (kJ/g)$

$\dot{m} = measured,\ \chi_a\ estimated$



$\dot{Q}$ *from calorimetry*



Slide 13

Model Sensitivity to Uncertain Input

Example: Hot Gas Layer (HGL) Temperature

According to an empirical correlation (Quintiere *et al.*) substantiated by hundreds of fire measurements:

$$T_g - T_\infty = 6.85 \left(\frac{\dot{Q}^2}{A_0 \sqrt{H_0} h_k A_T} \right)^{1/3} \propto \dot{Q}^{2/3}$$

$$\frac{\delta T}{T} \propto (2/3) \frac{\delta \dot{Q}}{\dot{Q}}$$

Uncertainty in HRR measurements was roughly 15 % *to* 25 %,

Uncertainty in HGL temperature prediction varied by:

2/3 x 15% to 25% or 10 % *to* 16 %

A sensitivity analysis confirmed this relation.

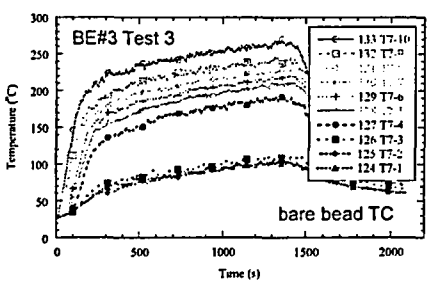
Model Sensitivity to Uncertain Input

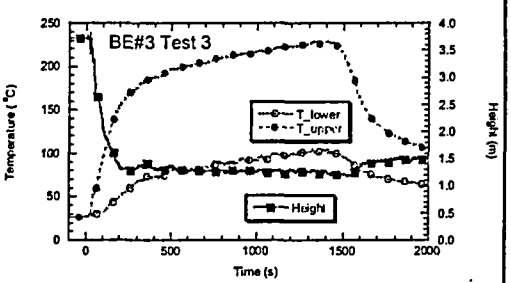
Quantity	Input Parameter	Power Dependence	Expanded Uncertainty, $\tilde{U}_{\mu}$ (%)
HGL Temperature, T_g	$\dot{Q}$	2/3	10
HGL Depth, z	$\dot{Q}, A, H$	Eq (5.4)	-1
Ceiling Jet Temperature	$\dot{Q}$	2/3	10
Plume Temperature	$\dot{Q}$	2/5 $1.3 < z/D^* < 3.3$ 2/3 $3.3 < z/D^*$	6 10
Flame Height	$\dot{Q}, D$	½	8
Gas Concentrations	$\dot{Q}$	½	8
Smoke Concentration	$\dot{Q}, y_s$	Eq (5.16), 1	18 **
Pressure	$\dot{Q}, A_{leak}, \dot{V}_{vent}$	2, 2, 2	no forced ventilation: 30 with ventilation: 75
Heat Flux, $\dot{q}''$	$\dot{Q}, \chi_{rad}$	from fire: Eq. 5.22 from upper layer: Eq. 5.24	22 15 **
Surface/Target Temperature	$\dot{Q}$	2/3	10

Experimental Uncertainty

Example: Hot Gas Layer (HGL) Temperature

- Gas phase temps were typically measured using thermocouples (TCs).
- HGL temperature and depth were determined using two layer reduction method.





- Propagation of error analysis considered the form of the two layer reduction method, and the uncertainty of the temperature measurements and TC locations.

Combined Uncertainty Results

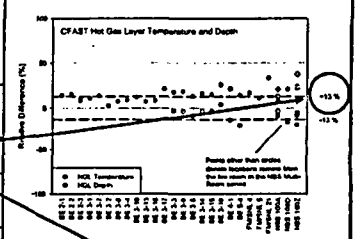
$$U_C = \left(\tilde{U}_M^2 + \tilde{U}_E^2\right)^{1/2}$$

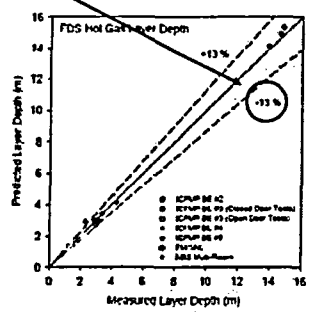
Summary of the Relative Expanded Uncertainties
Associated with the HGL Layer Depth and Temperature Rise

Series	HGL Depth			HGL Temperature Rise		
	$\tilde{U}_E$ (%)	$\tilde{U}_M$ (%)	U_c (%)	$\tilde{U}_E$ (%)	$\tilde{U}_M$ (%)	U_c (%)
NBS	13	2	13	10	10	14
FM/SNL	35	2	35	16	13	21
BE #2	6	2	6	6	10	12
BE #3	9	2	9	5	11	12
BE #4	33	2	33	25	17	30
BE #5	8	2	8	4	10	11

Representative Uncertainties

Parameter	Number of Tests	Weighted Combined Uncertainty (%)
HGL Temperature Rise	26	14
HGL Depth	26	13
Ceiling Jet Temperature	18	16
Plume Temperature	6	14
Gas Concentration	16	9
Smoke Concentration	15	33
Pressure	15	40 (no forced ventilation)
		80 (with forced ventilation)
Heat Flux	17	20
Surface / Target Temperature	17	14





Conclusions

- A quantifiable evaluation methodology is developed in which experimental uncertainty is used as a criteria for validation.
- Both experimental and model uncertainties should be considered.
- The determination of uncertainty is as important as the measurement itself.
- Experimentalists need to document and reduce measurement uncertainty to advance model validation.
- Magnitude of uncertainty can be used to prioritize efforts to improve measurement accuracy.