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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

DIGITAL INSTRUMENTATION AND CONTROL SUBCOMMITTEE

MEETING

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WEDNESDAY,

OCTOBER 21, 2005

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The meeting was convened in Room T-2B3 of Two White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 8:30 a.m.

MEMBERS PRESENT:

GEORGE E. APOSTOLAKIS, Chairman

MARIO V. BONACA ACRS Member

THOMAS S. KRESS ACRS Member

JOHN D. SIEBER ACRS Member

ACRS STAFF PRESENT:

ERIC A. THORNSBURY, Designated Federal Official

ACRS CONSULTANTS PRESENT:

SERGIO B. GUARRO

ALSO PRESENT:

CHRISTINA ANTONESCU
STEVEN ARNDT
PAUL EWING
WES HINES
BILL KEMPER
KOFI KORSAN
PAUL LOESER
THUY NYUGEN
RAY TOROK
MIKE WATERMAN
RICHARD WOOD

A-G-E-N-D-A

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

8:32 a.m.

CHAIRMAN APOSTOLAKIS: The meeting of the Advisory Committee on Reactor Safeguard Subcommittee on Digital Instrumentation and Control System.

I'm George Apostolakis, Chairman of the Subcommittee.

Members in attendance are Mario Bonaca, Jack Sieber and Tom Kress. Also in attendance is one of our consultants Dr. Guarro.

The purpose of this meeting is to discuss three sections of the NRC Staff's draft digital systems research plan and to hear a presentation from EPRI on their guidance for performing defense-in-depth and diversity assessments for digital upgrades.

During this portion of the meeting we will hear from the NRC Staff regarding Section 3.5 of the Digital Systems Research Plan, Emerging Digital Technology and Applications.

The Subcommittee will gather information, analyze relevant issues and facts and formulate proposed positions and actions as appropriate for deliberation by the full Committee. Eric Thornsbury is the designated federal official for this meeting.

The rules for participation in today's

meeting have been announced as part of the notice of this meeting previously published in the *Federal Register* on September 29, 2005.

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

It is requested that speakers first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

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

We'll now proceed with the meeting and I call upon Mr. Steve Arndt of the Office of Nuclear Regulatory Research to begin the presentations.

MR. ARNDT: Thank you.

Before we begin, Bill, do you have any comments or any statements?

MR. KEMPER: Yes. Thank you, Steve.

This is Bill Kemper.

We're going to present one of our last sections of the research report, Section 3.5 which deals with emerging technology. And in conjunction with that we have a couple of ongoing projects which we thought would be of interest to you, and we'd really like to get your insights on that. So that's why we've chosen these particular topics to present those to you. Okay? Thank you.

Go ahead, Steve.

MR. ARNDT: Thank you. As you mentioned, my name is Steve Arndt with the Office of Research.

I'll give a short introduction this morning and go over the general emerging technology and applications section.

With me at the table is Christina Antonescu who is the project manager in the Office of Research. She's been with the I&C section for 15 years, our longest serving I&C person. She has a background in electrical engineering.

Also with me at the table is Kofi Korsah-- I'll get it right. From Oak Ridge National Laboratory. He's one of the principal investigators that works for us and he's the project principal investigator for the emerging technology overview project.

And also our metal stressors project. He has a background as a Ph.D in nuclear engineering and over 20 years in the electronics and nuclear engineering area. So he's going to help us out this morning on this presentation.

As Bill mentioned, there are a number of projects in the emerging technology section. As we discussed earlier yesterday there's a series of programs and there's a set of different priorities associated with them, but based on both the urgency and the immediacy of the programs as well as the level of interest from our stakeholders.

These programs are not the programs that are here today, but the ones that we think might be here in the relatively near future. So we have both a specific set of programs that we're currently working, programs we're hoping to work on in the future based on budget issue and we also have a program to identify future potential emerging technologies. So that would basically in the 3.5 box. It's not an individual project in and of itself; it's a project to look for new trends. And what we're going to do today is I'm going to give you a very brief overview of the program and then Christina and Kofi are going to talk to you about our program to identify new programs. And then we will go into the current specific technology programs that we're working on right now, which are identified in the green boxes.

The idea basically having an emerging

technology program is that vendors, licensees, owners groups continue to develop new technology based on economic issues, based on the new technology itself, based on obsolescence; any a number of different issues based on daily research and what they do, based on university research. And we want both to be knowledgeable of what's happening, monitoring in essence what's going on, some of our projects are at the monitoring level, but also develop new regulatory criteria for our stakeholders. And this tends to be a broad based type issue for NMSS, for NRR and NSIR.

So this area, as I think I mentioned before, is more involved in understanding the technology than the direct ramifications.

CHAIRMAN APOSTOLAKIS: Well, there is no user need from these organizations, is there?

MS. ANTONESCU: There is.

MR. ARNDT: There is in some cases.

CHAIRMAN APOSTOLAKIS: Okay.

MR. ARNDT: So the programs we currently have are the emerging technologies evaluations, which I mentioned, an on-line monitoring project. This is a project that is specifically looking at what are the technical issues and the implementation issues associated with on-line monitoring techniques.

The broader area is systems diagnostics, prognostics and on-line monitoring. What we chose to do last year was to take the specific piece out of that program on on-line monitoring and investigate that, primarily because of the industry movement in this area. And we're going to go through that in detail later this morning. But the basic reason why we're looking at that particular program is because of the fact that the industry is looking to do tech spec changes to use on on-line monitoring for instance for calibration extensions.

So we're also looking at wireless technology. As you heard yesterday morning there's some issues associated with that both general technology issues as well as specific application issues.

We also have a set of future projects. The follow-on to the on-line monitoring program will be the general system diagnostic and prognostic program. And that will probably start in '07.

We have a program in advanced instruments that will start probably later this year looking at specific new instrument technologies that are becoming available as a basis of output of the various research.

We have an advanced controls program that will probably start in '07. This basically is looking at primarily advanced reactor type control issues, diagnostic issues associated with fully integrated control rooms and those kinds of things, the double bed modular control room, the full issues and things like that. But also issues associated with nonnuclear issues like fuel fabrication systems and distributor control systems and things like that.

We have a program looking at radiation harden ICs, which will also start on '07. This is looking at this from two different issues. One is the issue that we talked about yesterday to some extent. Because ICs, general ICs are becoming much more compact and lower voltages, et cetera, the single event phenomenon is a problem, basically, cosmic rays and things like that. So we really want to understand whether or not this going to give us a problem or not.

The other side of that is actually looking at whether or not ICs could reasonably be used in a harsh environment, whether or not that's a rational thing to do.

We have a program that's going to probably start on '07 or '08 to look at applications specific ICs, basic and build programmable beta rays. These are methodologies to do specific hardware solutions at a lower cost and a lower production run than specialty chips. And there's several people in the world nuclear environment that are very, very interested in this area. Toshiba is working very extensively in the build programmable beta ray arena. And from the preliminary indications they may be coming in next year, as early as next year with an application. So there's a lot of issues in this area.

EDF is also very interested in this area. I actually met with them on Wednesday to look at these issues.

So that's one of the areas that we're specifically looking at, not only because we think the emerging technology is important, but also ones that we're hearing from the outside world are going to be on our doorstep.

And the last area which will be probably an '07 start as well is the smart transmitters area. Understanding how the instruments particularly and also transmitters in any number of field components can affect the system indications and those kinds of issues.

So those are the programs that we're looking to investigate.

As I mentioned, we also have a specific program to evaluated on a continuous basis new technology. And I'm going to turn the rest of this time over to Christina and let her talk about that particular program and how we look at what's coming in the future.

MS. ANTONESCU: Thank you, Steven.

So the introduction of new instrumentation and control technologies into commercial nuclear programs is a slow process owing to the need for robust and reliable equipment of systems. Yet technological advances are being made continually and rapidly for other applications, such as consumer products and industrial plant systems.

Eventually technologies emerge that end up implemented in nuclear power plants. In this project we scan for new developments that will have an eventual impact and then report on the progress and the implication of those emerging technologies. So the need for evaluating emerging technologies comes from reviewing our needs, NRR-2002-017 the Research Office included a project to put forth this evaluation research plan between 2001 and 2004. And the benefit of this work is that NRC will better be prepared to make future regulatory decisions in these areas by becoming informed of emerging I&C technologies and applications in a timely manner.

Let me tell you what we have done so far. Our office initiated a study on emerging technologies as an ongoing project, as Steve has said. Our approach is to survey significant technological advances in I&C technologies. Assess prospective applicability in these advances for nuclear power plants. Identify potential research needs. Confirm elements of NRC Digital Research Plan, and contribute to updated I&C Research Plan.

So the reviews are presented periodically as reports. We have NUREG/CR 6812 that was published in 2003. And the next survey has been documented as a NUREG for this year, and we're going to talk about it in the next couple of minutes.

And we have specific technology that is going to be targeted for more detailed treatment. And we are going to have periodic surveys every few years.

CHAIRMAN APOSTOLAKIS: Now when you say "identify potential research needs for consideration," what exactly do you mean?

MS. ANTONESCU: Well, some of the results, what the lessons learned from these surveys that we have done, we're going to incorporate in our research and just identify --

CHAIRMAN APOSTOLAKIS: Why?

MS. ANTONESCU: So we can identify what areas we would like to spend more time and work on.

CHAIRMAN APOSTOLAKIS: And why?

MS. ANTONESCU: Because we'd like to, as Steven has mentioned in the I&C plan, identify this particular item, you know, emerging technologies is something that we like to look into --

MR. KEMPER: This is Bill Kemper. If I could just embellish.

This program really is their antenna. They were out looking over the horizon for new technology that we suspect will be submitted to us for review and approval in digital applications. That's the sole purpose of why we're doing it that way.

CHAIRMAN APOSTOLAKIS: I think it would be useful to emphasize instead of saying potential research needs. You should focus on the needs of the agency and make it explicit. We're going to review something, as Bill just said, or general maybe for some other reason. In other words, in the message we should be consistent that we're supporting the regulatory procedures of the agency.

MS. ANTONESCU: Right.

MR. KEMPER: Yes, but --

CHAIRMAN APOSTOLAKIS: There's research needs. I mean, we're not really a research institution.

MR. LOESER: This is Paul Loeser. I'm with NRR.

In this aspect we asked them to go out and look at basically all the things that may be used sometime in the future because we don't have time to attend all the conferences and read all the papers.

The idea was, and this is sort of what happened, that they then come back to us with a report like this of what they'd like to do. We look through it and we comment on it. And if we think that something is not necessary --

CHAIRMAN APOSTOLAKIS: Yes.

MR. LOESER: And this is based on what we heard from licensees, what they're thinking about using.

CHAIRMAN APOSTOLAKIS: I am not objecting. I never had any doubt that that was the reason. What I'm saying is that when you communicate to others what you're doing, make sure that these others understand very well that you're focused on the agency's regulatory responsibilities.

MS. ANTONESCU: Right.

CHAIRMAN APOSTOLAKIS: Just saying research needs is not --

MS. ANTONESCU: I understand now.

CHAIRMAN APOSTOLAKIS: Yes, sir?

MR. KORSAH: This is Kofi Korsah.

Yes, you're precisely right. And some of the focus area like sensors, I'm going to talk about that in detail. And the reason why we fixed on those sensors is that they may have some regulatory impact in terms of genuine set point requirements, calibration developed and so forth. So it's very important, yes. That's exactly the focus.

CHAIRMAN APOSTOLAKIS: As I say I suggest that when you have a slide that says identify research needs, you're asking for a problem.

MS. ANTONESCU: I will --

CHAIRMAN APOSTOLAKIS: And even the Commission, as you probably know, is very sensitive.

MS. ANTONESCU: So our first report was published in 2003, NUREG/CR 6812. It presents findings and specific technology focus areas. And we came up with eight areas on sensor and measurement systems, communications media and networking, microprocessors, computational platforms, diagnostics and prognostics, control and decision, human-system interactions and high-integrity software. So those areas chosen because they cover a full scope of I&C technology in nuclear power plants.

And to illustrate the scope of I&C technology can be visualized from a hardware sense from the sensors to the electronics to the actuator and second in a functional sense from the plant through the I&C system to the human.

CHAIRMAN APOSTOLAKIS: Could you explain those two words of diagnostic and prognostics?

MS. ANTONESCU: Yes. My next couple of pages will go into more detail.

CHAIRMAN APOSTOLAKIS: Okay.

MS. ANTONESCU: And so I'm just trying to make the point that the report itself tried to focus in eight areas, and these are the areas that we covered.

Here are some findings of the first report.

Under the topic of areas of sensors and measurement systems, several new radiation and power and process centers were under development as a result of DOE research. As the Nuclear Research Initiative, NERI, International NERI, and Nuclear

Engineering Education Research, NEER.

In this report we recommended their progress be followed because they're being designed for nuclear power plant application and the expected improvements in operating margins.

And under this topical area of communications media and networking, the survey anticipated the application of wireless technology to increase because of their cost, availability and flexibility. And my next presentation will address our current findings in this research area.

Regarding microprocessors and other integrated circuits, the survey identified key I&C technologies that warranted long-term monitoring because of their significance for nuclear applications.

Some of the examples are radiation-hardened ICs, and we have a program that we will probably look into later on.

Then optical processors, nanotriodes. Nanotriodes functions as a transmitter and it's basically the semiconductor version of the old vacuum tubes.

Another the system-on-chip circuitry and this design approach, most of circuitry required for a system can be contained on a single IC.

MEMS, the microelectromechanical systems. They have a combination of electrical mechanical features in a very small package. And others.

Regarding the computational platform, ASICs application-specific integrated circuits and real-time operating systems were identified as technologies to be monitored.

It is possible that the high cost of dedicated commercial software-based systems would drive licensees to rely more heavily on ASICs base solutions for code upgrades and in newer plants. Regardless platform, the performance and reliability characteristics of operating systems must be well understood since many computational and control system will employ some form of an operating system.

CHAIRMAN APOSTOLAKIS: How is this related to the three platforms forms that were presented yesterday?

MS. ANTONESCU: I wasn't here.

CHAIRMAN APOSTOLAKIS: Well, the Westinghouse, the Framatome, what was the other one?

MR. KEMPER: Tritronics.

Bill Kemper.

MS. ANTONESCU: One of the ASICs

experimentation of digital subsystem is the 7300 ASIC based system by Westinghouse, which was developed in 1990s. And it is designed as an ASIC based replacement model for the --

CHAIRMAN APOSTOLAKIS: So it is an application-specific?

MS. ANTONESCU: Yes, it is an application-specific.

MR. KORSAH: Yes. Both the type, the Tritronics and --

MS. ANTONESCU: They are PLC based.

MR. KORSAH: Yes. They are PLC based, they're not ASIC based.

MR. KEMPER: Yes. This is Bill Kemper.

ASICs and FPGA specifically are an alternative design to PLCs, if you will. It's another way of accomplishing the same thing. They just use different technology.

CHAIRMAN APOSTOLAKIS: So what we saw yesterday was controller based?

MR. KEMPER: What we saw yesterday was a microprocessor running application software. These technologies are different in that it's a sea of gates, and-gates and or-gates. And the programmer uses technology to program those gates into solid state components, if you will. And the purpose and the goal is to eliminate application software and things like that. Therefore, it's a simpler application, less complex, less subject to failures.

This is a new technology that there is much interest in right now. As Steve said, we just met with EDF day before yesterday to talk about this. And it's probably one of the areas that we're going to be moving into here pretty soon to do some research on. Because I think someone said earlier, we do have applications that we believe are going to be coming in here in the next few years using this technology for digital.

CHAIRMAN APOSTOLAKIS: Is EDF producing these or they're also researching them?

MR. KEMPER: The EDF is researching them. In fact Thuy is right here in the background if he wants to speak to his project. They're in collaboration with, I think University of Virginia.

MR. NGUYEN: Good morning. This is Thuy Nguyen.

We are doing very active research on it. And we are trying to work with one of our vendors to help them -- I would say move for a solution for that.

MR. GUARRO: Just a comment on the field

programmable gate arrays. Are you aware of the problems that the aerospace industry is having with those at this time? There's been a lot of failures of FPGAs.

MR. KEMPER: I can speak for the NRC. I don't think we were. So, thank you. It's a good comment.

MR. WOOD: I'm Richard from Oak Ridge National Lab.

And we've been involved in the space nuclear program and we've looked quite a bit, and it's related because of similar staff. So we're aware of those issues, yes.

CHAIRMAN APOSTOLAKIS: Space nuclear you said. I think Dr. Guarro meant space.

MR. GUARRO: Yes. I don't think there is a basic difference in the devices. So, you know, I happen to be aware of what problems have occurred on satellites across the industry.

CHAIRMAN APOSTOLAKIS: Is there any reference you may want to give to the Staff so they can --

MR. GUARRO: Well, there are investigations going on right now, so I can look into it. And if I have some specific reference that is available, I will--

MR. ARNDT: We'll follow-up.

MR. KORSAH: Okay. This is Kofi Korsah.

Yes. Some of the problems that you'll face with FPGAs are the same as you're facing with most of the tester ICs because of the radiation effects. And one other thing that I'm going to talk about is some of the radiation hardness, things like phase change ramps and so forth.

So as the industry moves into rad-hard electronics and they can replace the FPGA components with rad-hard component, but it'll be the same kind of FPGAs. Only the IC technology will change. So that's one of the problems, the rad-hard electronics.

MR. NGUYEN: And this is Thuy again.

We are pretty aware of the different failure of ICs and FPGAs. And we are trying to provide solution either at the level of the FPGA itself or at the level of the over design of the system.

CHAIRMAN APOSTOLAKIS: I remember one of the presentations some time ago you mentioned that there is an effort to collect the data that's at Brookhaven Project.

MR. ARNDT: We actually have to programs

in our program. One is specific to failure modes and just for liability engineering issues. That's the Brookhaven Project.

We also have a general project, it's the International --

CHAIRMAN APOSTOLAKIS: Yes.

MR. ARNDT: -- Safety Program which is looking at failure updating the inclusion of specific applications. We're looking at it basically from two different aspects.

CHAIRMAN APOSTOLAKIS: And when will these projects produce?

MR. ARNDT: Well, I'd have to go back and look at my notes and get back to you.

CHAIRMAN APOSTOLAKIS: All right.

MR. ARNDT: But the Brookhaven should be later this year, first comsys report on the new data will be in two years, I think.

CHAIRMAN APOSTOLAKIS: That's International?

MR. ARNDT: That's international.

CHAIRMAN APOSTOLAKIS: I think have a meeting on the failures that have been observed will be very valuable to everyone.

MR. ARNDT: Okay.

CHAIRMAN APOSTOLAKIS: At some point in the next year. We are an agency that worries about failures, of course. So this is, in fact, of high importance to us.

MR. ARNDT: And we're trying to gather insights as we gather the data.

CHAIRMAN APOSTOLAKIS: Absolutely. So as soon as you have something that you can talk about, I think it would be a good idea to recontact Eric and --

MR. KEMPER: This is Bill Kemper again.

Just for clarification, this is a meeting to discuss failure of digital components around the world?

CHAIRMAN APOSTOLAKIS: Their experience.

MR. KEMPER: Their experience? Okay.

CHAIRMAN APOSTOLAKIS: It is not only nuclear, of course, but broader.

MR. KEMPER: Broader.

CHAIRMAN APOSTOLAKIS: Is Brookhaven looking at the broader experience?

MR. ARNDT: Yes.

CHAIRMAN APOSTOLAKIS: Because that will give us a much better idea of what is it we have to worry about.

MR. WATERMAN: This is Mike Waterman,

Research.

We mustn't forget that we have to go beyond this, obviously. We need this information first. Once we have this information we intend to take it to the next step of how does an NRR reviewer, for example, look at an ASICs system and review it to ensure it's safe? What kind of procedures do you use? Are there tools available? Things like that.

CHAIRMAN APOSTOLAKIS: Yes, that's --

MR. WATERMAN: So we need that fundamental understanding and then we need to move that into the regulatory arena so we have acceptance criteria, perhaps a rulemaking; I don't know. Tools, review procedures and then training for the Staff so that when an ASIC application comes in or field programmable gate array comes in, the person knows what to do with that application.

CHAIRMAN APOSTOLAKIS: Well, the other thing is, of course, is that you are testing the credibility of your methods. I mean, we were told sometime ago that at least some people at NRR were happy with the methods they had, right? And if we look at the failures, then we can try to figure out whether those methods we have are protecting us against those measures. That's one application.

MR. WATERMAN: Well, the procedures we currently have in the SRP are almost exclusively devoted to software reviews. With an ASIC you run into other issues about how is the ASIC itself created, is there a system on the chip also and things like that. We need to keep improving our review procedures to make our staff more and more efficient and effective.

CHAIRMAN APOSTOLAKIS: So that's a topic of great interest to us.

MS. ANTONESCU: The survey confirmed the need for continued monitoring of diagnostics and prognostics technologies. And they'll be like maybe integration of controller diagnostics for autonomous plant operation. It is expected that a great reliance will emerge on surveillance and prognostic methods to facilitate predictive maintenance. And methods for assessing accuracy, stability and reliability of diagnostics and prognostic techniques are appropriate candidates for near-term research. I think we'll talk about it later this morning.

CHAIRMAN APOSTOLAKIS: But you didn't explain what they need? You promised to explain what they need.

MR. KORSAH: Can I interject here? Yes,

diagnostics and prognostics, okay. Diagnostics would mean looking at errors. Okay. So you have built in intelligence to look at likely problems. Okay. Is it likely? Has it failed or what? Has this sensor failed, that type of thing.

So diagnostic prognostics is looking at parameters to predict failures. So, for example, if we're monitoring motor vibration, for example, and looking at the footprint and the built-in software will say that this is likely to fail, for instance.

So the prognostic methods will help predict maintenance type of thing. So that basically is the prognostics.

CHAIRMAN APOSTOLAKIS: Are all the methods then out there that -- I mean, if I do a Fermi analysis, that's a prognostic. We never call it that, but that's what it is.

MR. ARNDT: Yes, it is. And what we're talking about here is the ability to make real time and near-real time application to do prognostics in a plant and have both -- there's two sides of that. The technology side of the actual thing you're trying to deal with, tube integrity or pump vibration or anything else. There's also the products issues associated with it; how do you get that defined, how do you deal with that? A little more interesting the latter than the former. But those issues, particularly as you're dealing with longer and longer cycle times and look more and more on issues associated with the reliability of the system over the cycle time it becomes more of an issue.

Also, the very issue associated with you're going to extend the calibration intervals and testing intervals. In most case write the approvals down. We also say yes you can do, but you have to monitor it. So when you get into how are you monitoring, so that's both the diagnostics and the prognostics the more and more issues. So, you have that but there are a number of other issues.

MEMBER BONACA: I think there is a move actually of, you know, the industry in fact not to wait for failure of a component. They begin to instrument and monitor. And that's a challenge. But, of course, those are the ones improving performance in that they are not waiting to shutdown and repair something. But in the meantime you do have a number of challenges here.

MR. GUARRO: Well, a comment on what was said a moment ago about fault trace. I remember that there was work done many years ago in using a fault trace line as a diagnostic tool, actually. When you associate the model with real time sensor input, that would be a way of identifying root cause for a set of symptoms. Is there a revival of that type of thing? Because this, there was something called disturbance analysis, which was in 1980 or so.

MR. ARNDT: We're getting a bit far afield from this actual presentation. But, yes, I'm aware of that brilliant work. And to my knowledge that particular slant on it is not being done right now. This is more the traditional analysis of the data analysis and trends.

MR. GUARRO: And to send it in a prognostic of what is the diagnostic trends today. What is meant by diagnostics done.

MR. ARNDT: Diagnostics are basically things associated with understanding how things fail in a real-time environment. We have highly redundant systems. If you lose some redundancy, you want to diagnose that loss. So that you repair it and/or understand how it's failed so you don't have that problem not just from the long term root cause analysis issue but also real-time diagnostics.

CHAIRMAN APOSTOLAKIS: And why stability? Micro assist ability, reliability. I understand the accuracy of the reliability. But the stability, what does that mean?

MR. KORSAH: If your diagnosis system is software based, you know you fully tested it, then it is stable in that sense. That is it's no good if you -- the diagnoses system is not going to have errors that would in itself be a problem. Because you are going to rely on the diagnoses system to infer things. But if your system is not stable, then it's going to-- you know -- the thing that you are relying is itself going to give you problems.

CHAIRMAN APOSTOLAKIS: And you call that reliability of the system?

MEMBER SIEBER: Well, stability has a different --

MR. KORSAH: In a control sense, yes.

MEMBER SIEBER: In a control system if you have a self calibrated sensor, it will make a calculation that says I need to increase or decrease the zero or the proportional band. And you can make the change that it will generate from time-to-time to calibrate itself such that it becomes unstable and goes like this. And so I think that's what you're talking about when you're talking about calibration stability.

CHAIRMAN APOSTOLAKIS: And ultimately it becomes unreliable?

MEMBER SIEBER: That requires some definition, too. You know, you can gather information from an unstable system that has something to do with the parameter. The question is how big an error band will you tolerate, you know?

CHAIRMAN APOSTOLAKIS: Okay. Let's go on.

MS. ANTONESCU: In the area of control and decision, the most significant change expected may be the transfer of more and more of the decision responsibility to I&C systems. And consideration continue to be given to the role of human in nuclear plant operations and the capabilities and reliability of autonomous control systems.

CHAIRMAN APOSTOLAKIS: You know, that's a very interesting thing because this agency has shied away from getting into the business of decision making, although it makes decisions everyday. But formal decision making is not something that, again, has failed. So it's interesting.

I mean, does this include understanding modern theories for decision making, not necessarily I&C oriented? And when you say role of human in nuclear plant operations, you're going to probably have some psychologist telling you that they're going to get bored and they're going to make mistakes. And I don't know how much that helps you.

MR. ARNDT: This work primarily is focused on the issue of balance between human actions and automated actions in control and decision in real-time type issue as opposed to general decision making.

CHAIRMAN APOSTOLAKIS: But shouldn't you understand the general decision making process first before you go into how much of that will be done by the machine and how much by the operator?

MR. ARNDT: Well, there's certainly some of that associated with human modeling and machine modeling and things like that, of course, in the performance area. But this is an area that primarily is associated with what is reasonable, how do you balancing --

CHAIRMAN APOSTOLAKIS: Yes. There is a whole literature on the distribution of decision-making.

MR. ARNDT: Oh, yes.

MEMBER KRESS: Do you envision using expert systems for that, it'll be the process that a automated decision will be made?

MR. KORSAH: Well, this Kofi again.

Part of it could be expert system, you know like the virtual robot system, for example. So all that we're saying here is that we need to look into what part should be, you know, embedded in your system, okay, as opposed to what part should be given to the human operator. That's what we're saying here.

MEMBER SIEBER: But as far as normal decision making techniques are concerned, they are not taught to operators.

CHAIRMAN APOSTOLAKIS: They are what?

MEMBER SIEBER: Are not taught to operators.

MR. KORSAH: Yes, I know.

MEMBER KRESS: Well, really a criteria for making this decision, what goes to the human and what goes to automation, has something to do with the time you're asked, you know, to make the decision.

MR. ARNDT: Well, let me rephrase the question a little bit because we don't make that decision. That's something that the licensee --

MEMBER KRESS: The licensee has to do all of that.

MR. ARNDT: Right. We just review that, look at issues not only associated with the division, but also the issues associated with if the licensee is making -- complaining that such-and-so can be done by a human operator. For example, if the procedure is going to be going forward and have a particular mitigating action, the mitigating action as the operator identifies the transient and makes the action; those issues are something that we currently have no position on. This research is looking at those issues, but it's also looking at things associated with how do you evaluate the design decisions that they made associated with all the control algorithms and level of complexity of those issues.

As you know, even more things can on its face be a potential to now awareness issues to the operator. That whole set of issues and what we should say about this thing here.

MEMBER KRESS: I suspect that this --

MR. ARNDT: Yes.

MEMBER KRESS: But you cannot have tolerance in making these decisions.

MR. ARNDT: Yes. As a matter of fact we've had discussions with some of the people working on this and they want to automate --

MEMBER KRESS: They might want to automate most of theirs.

MR. ARNDT: A much higher fraction of their plant control.

MEMBER KRESS: Tolerance of the plant -- that decision will be part of the criteria --

MR. KORSAH: Yes, exactly. Transients the roles affect would be of the order of milliseconds or whatever, you know, that you meant to do the system cannot very well be taken over by the human operator. So this way you say that this has -- the decision will have to be with the --

CHAIRMAN APOSTOLAKIS: Wait, wait, wait now. You mean that's what it is to start saying the systems is --

MR. KORSAH: Well, not just starting but, you know, if there are transients midway, I mean whatever it is, you know and you need to shut down the system, but I mean if they --

MR. KEMPER: This is Bill Kemper.

But things that could be envisioned in the future are things like automated reactor startups. We don't do that now in our technology. They're all manual. Automated turbine startups, you know those types of things. Commsig systems could be totally automated. All that's done manually right now as far as I'm aware in the nuclear industry.

MEMBER KRESS: Automatic startups has probably been a new thing for PWR.

MR. WATERMAN: This is Mike Waterman, Research.

We've already seen some progression toward automated things such as digital feedwater control. In PWRs, you know, how many plant trips did we get trying to fill that darn steam generator when we were starting up and keep the level right. So they've gone to digital control to do that.

We've also gone away from automatic controls in, for example, in the B&W integrated system used to have a frequency component to it such that as the good frequency sagged or increased, the plant would increase or it would respond to grid frequencies. Well, they phased that out because they didn't want the grid to automatically change plant power.

So those are a couple of examples where you go to automated or you back away from automated, depending upon what the circumstances. And this is just an extension of that moving into other things such as in a B&W plant when you have an accident, one of the operator actions right now is to trip the reactor coolant pumps when subcooling is lost. That's an operator action right now. Should it be automatic where you just tie your subcooling margin monitor into your system and trip RCPs. Don't know, you know. So we need this kind of guidance to help us determine whether or not that's a safe thing for the operator to do or for the licensee to do.

MEMBER BONACA: Although, I totally agree with that, but in part you know we see so much better action because these plants were designed to have operator control. So it's very difficult to redesign and totally to eliminate that. That is one of the issues that I would expect that for new plants there will be at some point more and more designs that are conceived from the beginning with automatic actions. And we will see more and more of that. I mean, just frankly that's going to be a tendency we're going to see in everything those systems.

MEMBER SIEBER: Well, automation is the evolutionary process. The original plants were all manual. The only automatic controls you had was heater levels and steam generator levels. And, perhaps the thermostat on a pressurizer. Everything else manual. But it took a lot of people to run those plants. And the pressure is to minimize the number of operators you need, and that's what forces the automation.

And then there's some things that operators just can't think through fast enough that occur. That'll, of course, a degree of automation. But that's where the pressure is.

MEMBER KRESS: Yes. Even operator actions are almost autonomous because he knows the operating procedures and it says do this, do this and do this and they follow that. And so, you know, I don't see why that couldn't be automated.

MEMBER BONACA: There are examples, you know. You were talking about a EDF plant. The one that was built in Germany was highly automated was a requirement they were to step away from the board if you got into an accident. So you really don't know, it depends on the philosophy applied to your defense, the response to accident and transients. And maybe you can -- you know, there are examples of walking away from manual actions.

MR. ARNDT: In any case, we'll have a look at it.

CHAIRMAN APOSTOLAKIS: Speak also to the microphone, guys.

Okay, Christina.

MS. ANTONESCU: Then the area of high-integrity software. The survey findings confirmed the need for near-term attention in two areas, as identified in the Research Plan: Investigate objective software engineering criteria and investigate criteria for software testing. These two areas are relevant because with no consensus regarding necessary high-integrity software development and testing practices and current processes do not give comprehensive quantitative measures of quality and fidelity.

For the second report the same technology focus area were used, however an emphasis was based on emerging sensors. And the summary updates for the technology focus areas are provided. Specifically, the sensor measurement system technology focus area was selected for more detailed study because of the line of reasoning: The sensors are important because they have a direct bearing on operating and protection margins, and; new sensor design may be ready for implementation in the near term, and; this is currently one of the most active areas of development.

And the potential regulatory impact of each of the sensors is discussed in the second report.

MEMBER KRESS: What are you talking in the sensors in terms of information tracking?

MR. KORSAH: If I may comment here again. The substance that we focused on for this period, okay, was sensors that could be not for diagnostics. You know crisis monitoring, for monitoring, neutron flux, temperature, flow, pressure that type thing.

MS. ANTONESCU: And here are some example updates found in the second report. For sensors and measurement systems, the new sensors are being developed that are close to commercialization and Kofi's going to go over the silicon carbide detector, the fuel mimic power monitor and Johnson noise, he's going to talk more about it.

Some sensors are capable of high temperature operation and all sensors are applicable in retrofits as well as new plants.

The second area is the radiation-hardened electronics. Progress is being made but the technology is not yet ready for near-term application. And considerable effort is being expended in radiation hard IC development for space reactor application, as Richard has said earlier. This technology warrants monitoring in periodic surveys of every two years.

And Dr. Kofi is going to give some very specific examples now on sensors.

MEMBER SIEBER: Before you flip off that

slide, what is Johnson noise?

MR. KORSAH: Okay. I'm going to talk about it.

MEMBER SIEBER: Okay. I didn't want you to go by that.

MR. KORSAH: Right. Yes.

MEMBER SIEBER: And remain ignorant.

MR. KORSAH: Okay. As Christina said, we focused on this report on sensors, okay. And so I have just selected three sensors that we believe the most regulatory impact, okay, for detailed discussion.

This is the silicon carbide detector. And basically it's silicon carbide with a little fluoride deposited on top. The little fluoride going to attract the neutrons, so you have neutrons hyper reaction. And it is the adverse that will basically slow down as the electrons pass and you get a current.

Now what's so important about that? Well, because we are not very safety to gammas and they have a wide range of neutron monitoring dynamic range, they have the potential to be used to replace the current free sensors, source stream monitors, radiation monitors and powering monitors, okay. So we have basically one sensor replacing three sensors, as it were, okay. Good. So that's one.

Now, the report to be very accurate would ignore a acidity, and we have not had a chance to do a detailed analysis of the accuracy of acidity. But if it proved to be true, then the regulatory impact of that is that you may, you know, set point change -- change the set point is the change only because you now have a sensor is that very accurate with much lower certainty. The modules are tied down, that kind of thing. So that's the silicon carbide detector.

MEMBER SIEBER: Now those detectors deplete, right?

MR. KORSAH: They are using the depletion mode, yes.

MEMBER SIEBER: So you have to have a -- continually recalibrate them because they're not as sensitive as the --

MR. KORSAH: Well, we have very low leakage. We have very, very low leakage.

MEMBER SIEBER: Right.

MR. KORSAH: And therefore, drift is potentially much, much smaller. And therefore the long term degradation could be much improved. Okay. But we haven't had had a chance to look into details on that. But --

MEMBER SIEBER: It depends on the geometry of it, though? The thickness of the layers as to how much it depletes.

MR. KORSAH: Right.

MEMBER SIEBER: And how sensitive it is.

MR. KORSAH: That is true.

MEMBER SIEBER: And it's over all stability?

MR. KORSAH: That's why even though this has potential for very low drift, very high temperature applications, we still have to look into it in more detail. And you're right, because the thickness, for example, is only about 100 microns.

MEMBER SIEBER: Right.

MR. KORSAH: And this is of the order -- I mean, the one that I've been testing now, this is on the order of about 300 microns. So you're right, that -- you know, because it's small, you have that potential.

MEMBER SIEBER: Right.

MR. KORSAH: Even though, the characteristics of the detector itself makes it very, very good, you know, in terms of low drift, accuracy and all these kinds -- but you have to look at this condition.

MEMBER SIEBER: Is there anything I could read that would give me information so I could learn a little bit?

MR. KORSAH: Oh, okay. Sure. Yes.

MEMBER SIEBER: Okay. Maybe you can give me a reference.

MR. KORSAH: The other one that we looked into is the fuel mimic monitor. This has -- what it does basically is measure the heat, you know, heat energy as opposed to measured flux to get the power. This measure the heat energy.

MEMBER SIEBER: It’s better?

MR. KORSAH: Exactly. That's exactly why we look into it. And basically I had to draw a pellet in here, okay. And so when it heats up it has an RTD resistance measurement element in there, okay? And basically you put this in a Winston Bridge configuration, okay? And when the power decreases to a steady state level, then the heat transfer in the temperature and the coolant is uncomfortable, okay. And when it changes, the resistors, the heat changes the resistors change and therefore it unbalances the Winston, so you have to apply power into it to, you know -- and the power that you put -- the electrical power that you put into it, is a measure of the reactor power.

MEMBER SIEBER: Okay.

MR. KORSAH: So that very neat. And what is the regulatory impact? We think that, you know, because it had the potential of being accurate and a licensee can come up and say, okay, they can apply for higher rate in power plant because now they can look at the power level more accurately. And so that is the regulatory impact.

Right now, it's in the second generation mode, okay. In other words, they haven't done a lot of work. They also looking at the condition and drift and that type of thing. There is some drift. The ones that they're testing now is there some drift, okay. So in terms of application in the nuclear environment, I would say that it's probably five years or more down the path. So it's not there yet.

MEMBER SIEBER: Right now you use the nuclear just to measure neutrons --

MR. KORSAH: Right.

MEMBER SIEBER: And if you adjust that output to equal what a measure would tell you power is --

MR. KORSAH: Exactly.

MEMBER SIEBER: And then there's some error there which you compensate for in your regulatory structure. Would this be more accurate or less accurate?

MR. KORSAH: It would be more accurate.

MEMBER SIEBER: Okay.

MR. KORSAH: Okay.

MEMBER SIEBER: So that there's economic incentive --

MR. KORSAH: Exactly.

MEMBER SIEBER: -- to put this in other than it's like a neater instrument?

MR. KORSAH: Exactly. Yes. If all the other things pan out.

MEMBER SIEBER: So you may get -- an additional one percent.

MR. KORSAH: That's what we think.

MEMBER SIEBER: Yes.

MR. WATERMAN: Mike Waterman, Research.

This looks interesting. How long is your sensor?

MR. KORSAH: How long?

MR. WATERMAN: Yes, what's the length?

MR. KORSAH: It's on the order of several centimeters, but I can't tell exact.

MR. WATERMAN: So you'd need then spaced vertically over several different locations in the corridor to account for the fact of your flux?

MR. KORSAH: To get it through there.

MEMBER SIEBER: Well, you'd have to do that because the heat generation flux, you know it's not related to flux. It varies. Flux position varies and Xenon varies and all kinds of things.

MR. KORSAH: Right.

MEMBER SIEBER: So you have to average it over the corridor.

MR. KEMPER: This is Bill Kemper.

I think the thing that's unique about this is this is being proposed, at least ways the first time I saw it was, as an alternative to X-core monitoring.

MR. KORSAH: Right.

MR. KEMPER: So this is a radical change from what we've traditionally been dealing with for neutron monitoring.

MEMBER SIEBER: Well, it'll change the whole process.

MR. KEMPER: Exactly. Right.

MR. KORSAH: The other sensor that we chose because we think that it has good potential for proper Johnson noise, and basically if you have any resistive element, you have noise associated with it.

And so basically you can measure the noise and the noise is measure the temperature, okay. And the neat thing about it is that you can design it so that it is completely dependent on the resistance. Everything is based on fundamental measurements, you know, I mean in terms of your -- for example --

MEMBER SIEBER: Well, different materials give you different noise characteristics.

MR. KORSAH: Yes. But the noise voltage depends, for example, you know this is not very visible. But it depends on your -- which is a constant, right?

MEMBER SIEBER: Right.

MR. KORSAH: Okay. Temperature then the resistance. And if you do a ratio, the measurements will go up – they all go up, for example.

MEMBER SIEBER: Right.

MR. KORSAH: So basically then your temperature measurements will depend only on constants, okay? That is the bandwidth of your instrumentation, right?

MEMBER SIEBER: Right.

MR. KORSAH: The bandwidth can be set as constant is constant, right? So everything then is just basically put on temperature. Everything is a constant. And then the neat thing about it, because it means, you know, just this hot, and we know that, you know, at current temperature measurement and measurement devices, if you can have the temperature measurement device that is free of drift, you know, that calibration into the example, you know, can be -- you know can be revealed.

MEMBER SIEBER: So this acts like an RTD?

MR. KORSAH: Okay. This particular one, okay, I'm saying in terms of regular measurement, okay, you can do a ratio, okay, of the noise and the resistance value can’t go down right?

MEMBER SIEBER: Right.

MR. KORSAH: Okay. So the only problem here is that in order for you to do a good temperature measurement you have to integrate it for a long time, okay. And because you have to integrate it for a long time, the response is not strong, it's slow, okay. Exactly. So even though you have that, you have the problem of long integration time.

MEMBER SIEBER: Right.

MR. KORSAH: So with this implementation here uses at RTD for regular temperature measurement, right? But then it uses Johnson noise also for temperature measurement and it uses the value, which is more accurate, right?

MEMBER SIEBER: Calibrated --

MR. KORSAH: To calibrate the RTD exactly.

Roger is in fact one of the experts --

MR. KISNER: Yes. This is Roger Kisner from Oak Ridge National Laboratory. I work in the area of Johnson noise, have for some time.

Kofi's explanation was very good. Just in case you needed for information on it, basically you had mentioned something about different materials have different noise. And the answer is they don't. The noise has to do strictly with, and you can hardly read the equation that's up there, it's four times Boltzmann’s Constant times the resistance, whatever resistance you choose for material. That has to do with material. Times temperature over some band width of the measurement.

So I pick one material or another material, they all have the same noise. It varies some because of the resistance and, of course, because of the temperature. So you measure the resistance and now the only thing left to solve for is the temperature. And out of that over a period of time, because of statistical process, then the longer you measure the longer you integrate then the lower the uncertainty of that measurement becomes.

And as Kofi says, you compare that against your standard RTD measurement, calibrate your constants in that measurement, and now you have, as though you had someone always measuring, always calibrating this device on a continuous basis.

There are other formulations for this same Johnson noise in which you don't even need to measure the resistance if you can do it in a system to tune system. And effectively it drops out and becomes KT over C and receives the capacitance of the system. And I suppose that you can also invert it to get it so that it's an inductive space systems.

So there's lots of ways of doing this formulation, but it all comes down to fundamental physics. The noise that's generated because of the flitting about of electrons on a conductive structure, which has to do strictly with temperature and the agitation of that structure.

Does that help you in your --

MEMBER SIEBER: Yes. I keep thinking about the activity of electrons is a function of how tightly they're bound, which is a material --

MR. KISNER: There are other kinds of noise other than Johnson noise. There's a shock noise. There's one over F noise. There's, you know, various kinds of noise that occur. And they have to do more with how those bound, the structure of the material, phonon vibrations and effects of the material.

The one over F noise, for example, is present in all kinds of systems, electronic systems, probably financial systems. So it's all over the place. But the Johnson noise is a very specific noise that's associated with these electrons that are the free electrons in a gas state moving about in a conductive material.

MEMBER SIEBER: And they're not bound.

MR. KISNER: And they're not bound.

MEMBER SIEBER: Okay. Thank you.

MR. KISNER: You're welcome.

MR. KORSAH: One of the areas that at least I heard Steve talk about was rad-hardened electronics. We looked at what is coming down the pike in terms of rad-hardened electronics. It's very likely to come into the pipeline environment very soon. And we found out that there are rad-hard electronics to the systems right now that are becoming, you know, better and better, okay? One is silicon-insulator, okay. And one is chalcogenide where they're using the chalcogenide material with red-hardened CMOS process to make a system that we have now.

Now, I want to explain a little bit more about chalcogendie. These are group 6 elements like solidium, sulfur, compounds of those materials. Okay. In other words if you put one element outside of that group with one of the elements in that group, that is a chalcogenide material. And the big thing about that is that the exhibits is change, okay. In one phase it is very low resistance and in another phase it is extremely high resistance. Okay. And so there are now tests being done with phase change memories, called phase change ramps, okay.

So what is the regulatory implication? For example, smart transmitters today are not, obviously, in the right environment because most are susceptible to radiation. Right? But if down the line we have cheap P ramps again, just like that of phase change the system, then they are cheap, right. Then you can considerably have a system that are based on these chalcogenide, right? And then the plants can use these smart transmitters, we can easily in containment environments.

MEMBER SIEBER: And it certainly

simplifies calibration.

MR. KORSAH: Right. Exactly. Okay. So those are the kinds of things that we look at and so we say we have to look at what is coming down the pipeline in terms of phase change ramps, for example, chalcogenide based ramps.

MEMBER SIEBER: What about, besides radiation, other elements of a harsh environment?

MR. KORSAH: Yes, they are very temperature resistant, yes.

MEMBER SIEBER: Yes.

MR. KORSAH: Right. For the harsh environment, so those would be very good.

MEMBER SIEBER: So the only thing you have any problems with is radiation, effectively.

MR. KORSAH: Right. Right. If the application is for traditional environmental, okay, yes.

MEMBER SIEBER: Yes.

MR. KORSAH: And we are saying that chalcogenide materials are very rad-hard. Yes, very rad-hard. So that is one of the materials that people are looking at into for used to making IC.

MEMBER SIEBER: Well, that's where the economic benefit is, inside containment.

MR. KORSAH: Right. Right.

MEMBER SIEBER: Because of penetrations and the cost of running wire in containment is ten times what it is outside containment.

MR. KORSAH: In terms of other materials that people are looking at, these are basically the semiconductor version of the vacuum tube. So they have, you know, an element of micron-sized elements in the semiconductor vacuum tube. And they have a catalytic element, and we just inject electrodes and that type of thing. Okay. So we can turn this, basically, into a transistor.

Now, because the material itself it so rad-hard, that means that this -- devices based on this type of technology can very well find their way into harsh environments. So that's why we need to look at that now.

Now, to assess how -- what's the word? To assess how fast we will migrate to proper environment, we believe the nanotriodes really are in their infancy really, so they are not something that is going to come in tomorrow, okay? These, the chalcogenide materials are much more advanced in terms of, you know, they are testing --

CHAIRMAN APOSTOLAKIS: Can we speed it up a little bit?

MR. KORSAH: Yes, I hope so.

CHAIRMAN APOSTOLAKIS: Jack, are you satisfied or you have more questions?

MEMBER SIEBER: I'll try to control myself.

CHAIRMAN APOSTOLAKIS: Okay.

MR. KORSAH: Okay. So at this point I will give it back to Christina to make a completion.

MS. ANTONESCU: Well, I'm just going to say that we are currently evaluating the path forward for the emerging technologies project. We have to update the report every three years or so. I did come up with a small writeup on it. But we're debating now if it's necessary to do it every three years or maybe under the three years.

CHAIRMAN APOSTOLAKIS: So the next presentation is one wireless technology?

MS. ANTONESCU: Right.

CHAIRMAN APOSTOLAKIS: Okay.

MEMBER SIEBER: Ah, cell phones.

CHAIRMAN APOSTOLAKIS: What's happened? We lost Christina?

MS. ANTONESCU: All right. So my name is Christina Antonescu. I'm here to discuss confirmatory research that we are presenting conducting on implementation of wireless technology.

This topic can be found in the Section 2.5.6 in the Digitalized Plan covering 2005 through 2009.

And I have Dr. Paul Ewing with me from Oak Ridge National Lab. He's the principal investigator of our electromagnetic compatibility and lightening protection projects. His background is electrical engineering and he has 25 years experience with EMC and radio frequency transmission.

This project is ongoing. It began in 2001. And it is scheduled to be completed in FY 2007.

The objective of this project is to develop the technical basis for implement wireless systems in nuclear power plants. There were a number of reasons for undertaking this project. These include recent introduction of wireless systems into other industrial environments followed by the expected migration into nuclear power plants. And the wireless system will most likely be --

CHAIRMAN APOSTOLAKIS: Should that be impending migration "to" not "of"? Where are the wireless systems migrating to?

MS. ANTONESCU: All right.

CHAIRMAN APOSTOLAKIS: That's not what you mean, right?

MS. ANTONESCU: Right.

DR. EWING: We'd like to have wireless systems within plants now.

CHAIRMAN APOSTOLAKIS: So then you're objecting to the whole bullet then, huh? Anyway, it was just a -- but it's "to."

MS. ANTONESCU: To. All right.

CHAIRMAN APOSTOLAKIS: You've got to be careful with this Committee here.

MEMBER SIEBER: Some members, yes.

CHAIRMAN APOSTOLAKIS: Christina --

MS. ANTONESCU: Yes, sir.

CHAIRMAN APOSTOLAKIS: You don't really have to read every word that's on the slides. We can read them. You can just comment on the slides.

MS. ANTONESCU: All right. I will try to comment.

MR. KEMPER: This is Bill Kemper.

Before we leave that last slide, if you could go back, Paul. We have a glitch. At any rate, the point I was trying to make is on that previous slide it says wireless systems have potential to cause safety problems and it mentions cybersecurity breaches. You recall yesterday morning we talked about this in the cyber area. I want to be sure that we don't confuse you all.

This project had a basic component of security, but it was just a very broad brush, if you will. Very slight involvement in security. So this is not intended to provide everything that one would need to know or be aware of in terms of security for deployment of wireless technology. But it does cover the basic, the essential parts that at least says that anyone should be aware of. Okay?

CHAIRMAN APOSTOLAKIS: Okay. So where are we? We're on slide number three.

MS. ANTONESCU: All right. The project encompasses systematic evaluation how a wireless system might be implemented. In phase one now is complete and included identifying and assessing the state of wireless system and investigation of deployment issues.

Then phase two is ongoing and involves conducting confirmatory research to validate the findings of phase one. And also to establish the technical basis.

The phase one assessment of the state of wireless systems identified distinctive wireless technology features that could be used to distinguish between different wireless products, which I'm going to cover later on.

MEMBER KRESS: When you talk about wireless, you're talking about radio frequency?

MS. ANTONESCU: Yes.

MEMBER KRESS: Not infrared or -- okay.

DR. EWING: It could be infrared, it could be optical.

MEMBER KRESS: Okay.

DR. EWING: It could be.

MEMBER KRESS: Could be?

DR. EWING: But the main focus of the study was RFI.

MEMBER KRESS: All right.

MS. ANTONESCU: So these technology features could be used to distinguish between different wireless products. And these are the characteristics that we need to identify in order to understand the application and assess its safety implications.

Some of these features include -- they are listed here, and include the frequency specter where the product operates --

CHAIRMAN APOSTOLAKIS: What does

unlicensed versus licensed mean?

MS. ANTONESCU: Well, I'm going to go through some of these and one is license and unlicensed in my next one, but --

DR. EWING: -- unlicensed -- licensed band around 900 megahertz, 2.45 gigahertz, 5.7 gigahertz. And in the unlicensed band if you don't go over a certain amount of power, you don't have to go and get a license from the FCC for it.

CHAIRMAN APOSTOLAKIS: I see.

MS. ANTONESCU: So people pay fees to operate in the licensed band. There's no fee for the unlicensed.

MEMBER SIEBER: Well, the disadvantage of unlicensed operation is everybody is there.

DR. EWING: Right. And it's getting very busy.

MEMBER SIEBER: Yes. And so if you are worried about somebody interfering with the operation of your plant, you can go to any electronics store and buy devices or components to create a thing that will cause that interference.

DR. EWING: Yes, that is true.

MEMBER SIEBER: If you're licensed, though, you have to build it by hand. So you've got to be a little smarter cookie to do that than just going down to the local store and buying something.

CHAIRMAN APOSTOLAKIS: Okay.

MS. ANTONESCU: All right. So the network topology, I have the area to be covered, is another feature.

They also include the output power, typically a 100 milliwatts for transmitters in the unlicensed band and up to about 10 watts for the transmitter in the license band, I think.

It's information throughout. What I mean by throughout is they are in the network.

Then, whether the product is based on open standards or proprietary protocols, that is IEEE standards versus vendor specific.

And the type of modulations employed.

And I'm going to go through some of these features. And we need to talk about the selection of frequency bands that can impact the available options in wireless and the unlicensed frequency versus the licensed frequency.

The next one is the topology. It's typically influenced by size and complexity. And identification of the topology is necessary also because of before review of the application can proceed.

CHAIRMAN APOSTOLAKIS: So can you explain, for example, the tree network, what are we looking at?

MS. ANTONESCU: Yes. The small network might use the star topology, for example, while a medium sized or large network might use a tree topology.

CHAIRMAN APOSTOLAKIS: But what does that mean?

MS. ANTONESCU: Okay. Well --

CHAIRMAN APOSTOLAKIS: Explain the star network, for example.

MS. ANTONESCU: Okay. In a simple network in a small facility might use a star topology and a more complex network spread throughout the plant and use a tree topology. For a network designed to automatically reconfigure itself when the new nodes are introduced or what is commonly known as a mobile rad-hard network, the mest topology is used because of its flexibility. And so it depends on the ease to control, the --

CHAIRMAN APOSTOLAKIS: You assume too much. I'm asking a very simple question. Explain the star network. What are spheres we're looking at?

MS. ANTONESCU: These are different

topologies of a network that is necessary and depending on the facility that --

CHAIRMAN APOSTOLAKIS: No. You're explaining the different networks. I'm --

DR. EWING: Each sphere represents --

CHAIRMAN APOSTOLAKIS: What's a sphere?

DR. EWING: -- a receiver and a transmitter--

CHAIRMAN APOSTOLAKIS: What is sphere? What is sphere? What is it?

DR. EWING: You have a hub there in the center and you have the different nodes on the outside which might feed back into a hub if you had a tree network. Those might be a sub --

CHAIRMAN APOSTOLAKIS: So are these --

DR. EWING: -- which feed might feed back into a larger network or something.

CHAIRMAN APOSTOLAKIS: So one sphere is what? A sphere, is it telephone or what is it?

DR. EWING: Oh. It might be a RF modem or something. It might be just the sensor node or something.

CHAIRMAN APOSTOLAKIS: Okay.

MEMBER KRESS: It'll be a PC, right?

CHAIRMAN APOSTOLAKIS: So if two spheres

in the star network were to communicate, they will have to go through the central --

DR. EWING: Right. Through a hub, yes.

MR. KEMPER: Yes. The little spheres are a communication device.

CHAIRMAN APOSTOLAKIS: Okay. That's what I wanted.

DR. EWING: Communication. Sorry.

MR. KEMPER: This is Bill Kemper.

CHAIRMAN APOSTOLAKIS: The questions sometimes are very simplistic.

MS. ANTONESCU: Okay.

MEMBER SIEBER: When you set up a network on your PC as to which of the two on the left you want to do? That's the way to designate the protocol.

MS. ANTONESCU: Then another feature is the area that can be covered by a network, which is typically determined by the type of network being deployed. A personal area network covers an area in the order of tens of meters. And a local area network covers in the area of over 100 meter. And the metropolitan or white area covers in the area of kilometers in size.

It should be noted that the standards have been developed that specify how each type of network will operate. And along with its specific area of coverage, each type of network has designated beta throughput rate and bandwidth operation. And we're going to discuss some of these familiar types of networks in the market today, which include Wifi and Bluetooth, WIMAX.

The wireless products available today also employ different modulation techniques. And these techniques are typically selected for their practicality and robustness. And identification of the modulation technique is necessary also before a review of the application can proceed.

And these are the three modulation techniques: The frequency hopping spread spectrum modulation that directs the spread spectrum modulation and the orthogonal frequency division.

And the next page, as we stated earlier, the wireless products available on the market today are being influenced by the wireless standards. And NRC has to understand these standards before they can assess systems that may be installed in nuclear power plants.

So if you look at the table which summarizes some of these features that we mentioned before, you can see on the first column shows the different available standards. 802.15 which is Bluetooth and ZigBee, then WiMAX you got 2.16b. And the Wifi to different versions.

And then the next three columns show the modulation techniques for the particular standard.

And the columns that follow show the operating frequency, the size of network, the coverage area and the data throughput.

And I think for the power plant, the Wifi is the most widely used.

As previously discussed, the type of wireless system and relevant features must be identified to determine its suitability for an application. And one key issue is the compatibility of wireless system with the environment in which it will utilize. So the physical layout of the wireless components and desired coverage area must be assessed.

Another area that we looked in phase one is the deployment issues associated with the wireless system. And the deployment issues identified where NRC acceptance criteria is needed. And ongoing work under this program is intended to establish appropriate acceptance criteria and develop necessary tools to support the review of wireless applications.

So the deployment issues include the

susceptibility of electronic devices to interference from other devices, wireless devices, the impact of available wireless products on the market, the security wireless networks and the type of installation practices that would have to be used, and the impact of emerging wireless technologies.

And we did key issues associated with the deployment of wireless system were identified.

Next page, our investigation also showed that EMI interference effects could possibly impact the digital I&C safety functions linked to wireless devices. And the occurrence of interference between 802.11, which is Wifi devices and the Bluetooth, the 802.15 have been documented. And 24 of 79 channels were found to be susceptible to interference from the 802.11b, which is are the Wifi networks. That is that the 24 of the 79 channels available for Bluetooth did not work. And the Bluetooth interference to 802.11g networks also was found to be similar.

So redundancy is one means of addressing some potential interference.

Then the security was also being considered. As Bill mentioned, we have current plans to initiate the following research project to perform a detailed investigation of the security issues.

A layered approach to security measures recommended to defend wireless networks . And this is a list of security measures. It's not intended to be all encompassing. It's not even close. But a layered approach should include the list that I mentioned, here on the list: The password protection that is the user access control; encryption, that is the need for a special code to know what the signal is saying; administrative controls that is limiting the use of wireless devises in certain areas; network diversity, it's firewalls, access management that is limits access to network when roaming, and; signal strength management.

Some certain conclusions were derived from this investigation. The overall implementation of wireless systems in the nuclear plants will require NRC oversight to ensure safety based on the deployment issues that we will discuss.

And safety considerations in the nuclear environment will warrant stringent wireless-related security measures. And we do have a follow-up project that is scheduled to evaluate these wireless security measures.

And the systems have the potential for interference with other plant systems, and hence the

EMI guidance should be followed.

Lastly, the prudent use of redundancy might be required to ensure reliable operation of wireless systems in nuclear plants. And we also have some other considerations such as independence, electrical isolation that are also relevant.

CHAIRMAN APOSTOLAKIS: Are you aware of any instances where we are implementing imprudent use of redundancy?

MS. ANTONESCU: No.

CHAIRMAN APOSTOLAKIS: Is that what we call a motherhood statement? Also your first bullet.

MEMBER KRESS: Is there a fatal flaw in radio frequency, it can always be overridden and interfered with. You can’t shield it completely.

DR. EWING: No. It's not a matter of shielding. It is maintained and robust to operate in any wireless, making it secure enough where you have a set of signals encrypted.

MEMBER KRESS: Regardless of the strength of what it is?

MEMBER SIEBER: If you wanted to mess up a control system using wireless in a nuclear power plant, you don't need to know anything about the protocol or encryption or anything. All you need is a stronger signal to wipe it out.

MEMBER KRESS: That's what I was thinking.

MEMBER SIEBER: So where's the point of that control?

DR. EWING: Well, the manipulative source of that interference was far enough distance away by the time you got to the equipment, then --

MEMBER SIEBER: You might have --

DR. EWING: -- be a stream that's --

DR. EWING: You might have to build a big one.

MEMBER SIEBER: Yes.

MEMBER KRESS: The infrared doesn't seem to have any problem.

DR. EWING: No, it doesn't.

CHAIRMAN APOSTOLAKIS: Okay, Christina.

MS. ANTONESCU: So the research is now being performed in phase two on the project to validate the entire phase one. And we're developing evaluation tools that mimic the operation of multiple wireless systems. And can confirm wide RF propagation coverage. We're also assessing the EMI issues associated with co-locating wireless technologies for confirmatory research, that is validating the tools with real data and that is measurement done in the lab, probably.

So the results of the project are progressing as planned and we do have a NUREG/CR which was completed in July 2005, and it's called Assessment of Wireless Technologies and Their Application at Nuclear Power Plants. And the phase two effort is proceeding on course. We're looking on a second NUREG/CR entitled Assessment of Industrial Wireless Protocols. This first draft was completed in March, 2005 and it reports on the modeling and simulation progress to that point. It will be updated in March of 2006 to report on the conclusion from phase two.

And in conclusion, the project will continue through 2007. We'll continue to develop the wireless systems evaluation tools along with validating the simulation models. We'll complete a second report to document the evaluation tools and develop training materials for live wireless evaluation tools. And in addition, we will establish criteria for regulatory guidance for implementing wireless systems based on the findings of our research.

And I don't know if we have any time, but Paul, did you want to go over any of the backups?

DR. EWING: No, I don't think so unless

someone has questions.

CHAIRMAN APOSTOLAKIS: Any questions?

Thank you very much. Appreciate it.

We will recess until 10:30.

(Whereupon, at 10:09 a.m. a recess until 10:36 p.m.)

CHAIRMAN APOSTOLAKIS: Okay. We're back in session. And we have the last presentation, I believe. on 3.5.1.

MR. ARNDT: That's correct.

CHAIRMAN APOSTOLAKIS: Well, Mr. Arndt.

MR. ARNDT: Thank you, Professor Apostolakis.

Our last presentation today on another one of the emerging technology programs. This particular program is part of 3.5.1, which is the systems diagnostics, prognostics and on-line monitoring program. The first part of that program that we've taken on is the on-line sensor calibration issues associated with on-line monitoring.

With me today is the principal investigator Professor Hines from the Nuclear Engineering Department at the University of Tennessee, and he'll introduce himself more thoroughly a little bit later in the presentation.

We're going to give you some basic background, some motivation of why we're interested in this particular aspect of the program, the project objectives basically what we're trying to accomplish. Talk about the modeling methodologies, talk about the toolbox that we're developing to allow us to do much more detailed analytical studies. Look at some of the uncertainty and estimation issues, which is one of the key issues associated with this. And then give you some basic conclusions.

This has been an area of research for a long time. People have been looking at this area, particularly in the sense of calibration extension area because it's the most practical area. But various organizations throughout the world have been looking at this for 10 or 15 years.

The first major document on that was a work that we published in 1995 "On-Line Testing of Calibration of Process Instrumentation Channels in Nuclear Power Plants." And basically it was to look at the technology, to review the technology, to understand the technology and determine whether or not this was something that we should really keep an eye on because it was or was not going to be feasible in nuclear power plants. And the conclusions of that was that there are a lot of opportunities in this area and it is feasible.

In 1998, EPRI submitted a topical report in this area that we looked at, evaluated, write a safety evaluation report on it and basically concluded that the generic concept of on-line monitoring for calibration interval extension was something that was acceptable. However, we listed 14 specific requirements that must be addressed in a special plant implementation, and these ranged fairly standard kind of things. We had to good V&D and quality assurance things; just more specific technology issues.

We did not at that time look at the specific analytical algorithms associated with it. We basically deferred that to the individual application reviews.

In the last few years EPRI and a number of plants have looked at this both for diagnostic issues, the issue of understanding how the systems are working looking at both the safety and nonsafety systems from a diagnostic/prognostic kind of area as well as a specific application that we're talking about for sensitive calibration. As you've heard, there's been a lot of research associated with putting new digital systems in the plant, so there's several different applications of this. One is the specific tech spec type issues, but there's also other areas that we're going to get to after we finish looking at this.

The most pressing, shall we say, from a regulatory standpoint is the V.C. Summer plant, which is currently looking to submit a tech spec amendment to do calibration interval extension using on-line monitoring techniques. And they met with us in March and we are expecting their application shortly.

There is a number of different issues, and I'm just going to briefly go over a couple of them here before I turn it over to Wes to go over some of the more technical issues.

The assumptions inherent in the methodology are really the things that we're going to need to look at when we review these things for specific plant implementations. We've already looked at it both from a research standpoint and from a regulatory standpoint to approve the general concept that it's a rational thing to do. So what we're going to end up having to do in the specific application review is look at the details of how they're doing it and is it reasonable. To do that, you need to look at basically the devil in the details.

One of the big issues is the training

data. If you're going to make certain assumptions about how the plant operates and what the intervals are and how the things drifts and whether or not the surveillance is sufficient to negate the requirement to do calibrations, you have to understand the quality of the predictive models, the uncertainty associated with the models and the information that went into the models, basically the training data.

Another big issue is the plant operational statements because: (1) You're making certain assumptions on how the plant will operation; (2) you're getting your data from past operations. So you have to make sure that whatever you trained the data, the system on, is the same state that you're actually operating the plant in.

There's also a number of issues associated with the fact that you're extending the calibration intervals, you're going to have to do various kinds of techniques to avoid common mode failure, drift limits and various other things. So you have to look at the assumptions associated with that and make sure they're implementing them in a reasonable and rational way.

So we organized the project basically in three phases. The first phase is basically to update the state-of-the-art. Where are we today as opposed to what we've looked at in the past? What are the issues? What are the technical challenges associated with it? How does that related to the 14 points that were required in the SER?

The second part, as we mentioned, we didn't do a detailed analysis of the theoretical issues for the actual algorithms. So the second part is to look specifically at those algorithms and understand what are the technical issues, what are the bugaboos, what are the questions that a reviewer needs to ask to make sure that they get the information, they get the data? Also, what's the answers that they should expect when they ask those questions?

The third part is to develop an actual tool to help the reviewer do audits if they want to of the actual analysis and information that's provided. And also to do some worst case scenarios using that tool as basically a reference document for the reviewer.

So, for example, we'll use some plant data and come up -- well, if they're right on the bad edge of this particular side of the box or that side of the box, what kind of information are you going to see. So we're going to have a state-of-the-art information on how the system works, we're going to have a tool to allow the reviewer if he wants to do so some independent audit calculations, and we're going to have a reference document to say these are the outputs that you might want to have a concern about.

CHAIRMAN APOSTOLAKIS: The bullet before last, do you mean winter of 2006?

MR. ARNDT: Yes. That's a typo. I told Eric, I accidentally sent him the version before the last version of this.

At this point I think I'm going to turn it over to Wes and let him talk a little bit about some of the details.

MR. HINES: Okay. I'm Wes Hines, and from the University of Tennessee. Let me give you a quick background of where I come from.

An ex-nuclear qualified Navy submarine officer. I studied Ph.D under Don Miller. Then I left and went to the University of Tennessee. I've been there about 11 years. I went there to work with Bob Uhrig and then take over his program when he left.

I've been working since -- I guess my first project in this area was in 1995. This is my major area of research. I've had continuous funding from multiple funding sources for probably the last ten years in this area.

Uncertainty analysis methods. The SER, actually about five or six -- maybe five of those 14 points had to do with quantifying the uncertainty of these empirical models. So these models that are being used are empirical models. There are quite a few of them listed here. It includes equations for MSET. MSET is a technique that was developed by Jack Mott and used at Argonne National Laboratory, highly publicized by Kenny Gross and used quite a bit. The early adopters used MSET.

Autoassociative neural networks, that's the techniques that's being used at the Holland Reactor Project with Paula Fantoni.

Autoassociative kernel regression is a technique used by a company called Expert Microsystems in California. That's the product that was used by EPRI in most of their implementation plans, although MSET was used out at Palo Verde with a company called Smart Signal in Chicago.

The neural network or NNPLS partial squares is an alternate method that the Holland Reactor Project is using.

So the technique, the empirical modeling techniques that we've examined are the empirical modeling techniques that are being used out there right now and experimented with and pilot studied at nuclear power plants.

There is one nuclear power plant that's actually on-line calibration monitoring for calibration. It's a little bit different. They have digital control systems instead of having just four redundant sensors, they'll have eight redundant sensors because they don't just need redundant sensors, they redundant systems. So it's a little bit easier and AMS is doing that work and basically using averaging techniques. And you can do that when you have so many redundant sensors.

But anyway, the SER really had a lot of focus on what's the uncertainty of these empirical model. So there's two major methods of determining the uncertainty of the empirical models. One are analytical methods which are basically derived from Taylor series expansion so you can equations that actually tell you what the uncertainty is. It basically tells you the variance portion of the uncertainty.

The other techniques are Monte Carlo based techniques. Basically you sample and you build a couple of thousand models and you look at how do the outputs vary. And that, again, will give you the uncertainty portion or the variance portion of the uncertainty.

So two different techniques.

Uncertainty of empirical modeling has two components. It has a --

CHAIRMAN APOSTOLAKIS: Excuse me.

MR. HINES: Yes, sir?

CHAIRMAN APOSTOLAKIS: When we were looking at the Latin Hypercube Sampling technique way back in NUREG-1150 there was a general consensus that this method gives you a pretty good estimate of the mean value, but not such a good estimate of the variance. So now things have changed? I mean, people passed the variance?

MR. HINES: No.

CHAIRMAN APOSTOLAKIS: I think it depends a lot on how many intervals you consider, right?

MR. HINES: Some of it has to do with the application. I mean, these are just -- monochromatic techniques means just techniques that you do over and over again and you're looking for a variance.

CHAIRMAN APOSTOLAKIS: Yes. I know that. Yes.

MR. HINES: Latin Hypercube Sampling is just a method of speeding up Monte Carlo.

CHAIRMAN APOSTOLAKIS: I know, but --

MR. HINES: And it's a way that you can reduce the sampling.

CHAIRMAN APOSTOLAKIS: -- you pay a price for speeding it up.

MR. HINES: And there are two major techniques. Latin Hypercube Sampling was used by Argonne and it's hard to tell exactly why they focused on that technique so much when you can use direct conventional bootstrapping techniques. And we've done experiments and shown that you get about the same results. We've looked at convergence rates to see how much time does the Latin Hypercube Sampling actually save you. And there's a lot of additional assumptions that you need to make when you do the Latin Hypercube Sampling. You have to know the noise distributions on all your sensors. You have to make a lot of additional assumptions. And the report that we've -- the second NUREG that we're publishing goes into detail on how the two different techniques work, how they differ, what the conversion rates are. They both give you basically the same results if you run enough samples.

The bias portion -- well let me go to the next slide.

CHAIRMAN APOSTOLAKIS: Yes.

MR. HINES: The uncertainty of an empirical model is quantified, it can be decomposed into two components. A bias, which is basically the difference between the expected value against a true value and a variance, which basically expected value of the variance around your mean prediction. So the total uncertainty is the square root of the variance plus the bias squared.

And you have to quantify these two components separately. All right?

CHAIRMAN APOSTOLAKIS: Say that again. The total is what?

MR. HINES: The total uncertainty is these two combined. It's the square root of the variance squared -- of the variance plus the bias squared. It's not shown here.

CHAIRMAN APOSTOLAKIS: The units don't come out right.

MR. HINES: Well, bias squared -- I mean, variance is the square of the units.

CHAIRMAN APOSTOLAKIS: Yes.

MR. HINES: So you have to square the bias and add it to the variance.

CHAIRMAN APOSTOLAKIS: Yes. But you said

the square root of the variance.

MR. HINES: Well, the square root of the variance would be the same deviation, right?

CHAIRMAN APOSTOLAKIS: But you don't --

MR. HINES: You have feet plus or minus certain number of feet, so you have to take the square root of the variance to get the standard deviation.

CHAIRMAN APOSTOLAKIS: But to get the total you take the variance and you add to it the square of the bias, is that correct?

MR. HINES: Right. And then you --

CHAIRMAN APOSTOLAKIS: Okay. That's not what you said.

MR. HINES: No, I said the square --

CHAIRMAN APOSTOLAKIS: But that's what you meant. Okay.

MR. HINES: -- of the variance plus the bias squared. Yes. I couldn't show you where my parenthesis where in my head. My parenthesis are about here. Bias squared variance, you put them both out and put in the square root sign.

Okay. So you have to calculate these two things separately. The past people like Argonne who did some of the early uncertainty analysis for MSET, they only did the Monte Carlo technique and they were looking at the variance. So they were basically saying that they were unbiased models. And it's a pretty good assumption when you're in the middle of certain operating conditions. But you need to take both of those into consideration.

Analytical equations for variance are different for each of the different models. For the autoassociative kernel regression, the autoassociative MSET techniques it looks very similar to what you get from linear regression where this matrix would just be the X matrix and you'd have a Fisher information matrix.

Autoassociative neural network, again it looks like a lot like what you'd get for linear regression, but it's a nonlinear format. And it uses a Taylor series expansion and there's a few assumptions there.

But these techniques have been developed or in the statistical literature. We've applied them to nuclear power plant data. We've bootstrapping techniques to validate that, yes, they do give you the correct results. So you can either have analytical techniques running on-line with your model, or what's more prevalent in industry right now is that they would use Monte Carlo techniques and they would take average values for models, and say here's my uncertainty of this model.

So an analytical technique would give you a point wise uncertainty value while a Monte Carlo technique would just say, you know, you're 95 percent confidence is this is your uncertainty value. So there's differences in how people might try to quantify the uncertainty.

Monte Carlo uncertainty, and the early work and you still see it presented it this way in technical conferences, someone will use one empirical model. They'll get a prediction through time. They'll measure the variance of that prediction and they'll say that's the uncertainty of my model. Well, that's a variance of one model, that's not the uncertainty of your technique.

So Monte Carlo technique basically you sample from the date, you develop a model. You sample again, you develop another model. You develop a 1,000 models and you look at the variance between the models. So you're getting a true estimate of what do you think. You know, how repeatable are your modeling results. And with these techniques, that's extremely important because the data that goes into these models are highly collinear, highly correlated. And when you model with correlated data you get what's called an ill-posed problem. You can get huge variances. And one model looks good, but you need to do it over and over to make sure that you get consistent, reliable, repeatable results.

So you build these results. You use an independent test set and you calculate these variance parameters. And that's one component of your uncertainty.

Conventional bootstrapping you just sample right from your sample, your data sets. And we'll contrast that with what we get with this Latin Hypercube Sampling. If you just look at the number of blocks on the sheet, you can see it's much more complicated. You have to take the actual data. You have to de-noise it and Andrian Miron from Cincinnati published a Ph.D. dissertation and he went to work at Argonne and they've developed these de-noising techniques that they think are extremely good. And they're pretty good, but there are some things you need to watch out for when you use them.

But you de-noise it to get distributions of the noise that's on your data and then you use the de-noise data and you sample from that, and then you sample from your noise distribution and you build your model. Then you do that over and over. And because you have the noise distribution, you can sample at a more intelligent manner and that's where you get into the Latin Hypercube Sampling and have fewer iterations to give the same reliability to your uncertainty predictions. So it's a much more complicated technique.

Bias estimation requires an estimate of the true parameter value. So you have to use some type of filtering or de-noising to do that. If you have redundant sensors, you can use independent component analysis which takes a group of sensor values and it can actually pull out the independent components. One independent component would be the actual process variable. Other independent components would be the noise on the process variable. So there are different techniques that have been suggested to use for de-noising. And we've gone through and implement these, different ones, and studied the assumptions and compared those different techniques.

CHAIRMAN APOSTOLAKIS: Let me understand what's going on here because I'm not familiar with all this noise.

MR. HINES: Okay.

CHAIRMAN APOSTOLAKIS: The whole idea of

a statistical analysis is to get, you know, an estimate of the true value?

MR. HINES: Right.

CHAIRMAN APOSTOLAKIS: With some uncertainty.

MR. HINES: Yes.

CHAIRMAN APOSTOLAKIS: Now here it seems like you're breaking up that into two pieces. One is the bias factor, this is already individual sensor, the bias factor?

MR. HINES: It's the bias -- if you have a model that's estimating what the true value of the sensor should give you, then your model will be biased and it will have variance associated with it.

CHAIRMAN APOSTOLAKIS: Right.

MR. HINES: And the analytical techniques and the monochromatic techniques give you the variance portion. They don't give you the bias. So you have to also find out what the bias portion of that is.

It's going to have some variance to it, it's going to have some uncertainty with it, and it's also maybe not going to be -- I'd have to say the mean may not be equal to the true values mean. And that's the bias. And that’s the reason I asked about the idea of the uncertainty of your estimate.

And the reason this is important because you might have a sensor that you assume the sensor can drift a percent over a certain interval of time. And if your prediction and you subtract the actual value, and that's your error, that's your residual. If that residual moves a half of percent and you're allowing it to drift one percent, if the uncertainty of your model is three-quarters of a percent --

CHAIRMAN APOSTOLAKIS: You're out.

MR. HINES: You'd better go recalibrate. I have a one percent drift allowance. And then you have to subtract off the model uncertainty because as it drifts when that uncertainty -- when the 95 percent confidence interval crosses that limit, now you're no longer 95 percent confident that that sensor has not drifted to one percent. So the uncertainty is extremely important because it really changes your drift allowances. And if you can't predict a value, you know, within the drift allowance, then you can't use these techniques at all. And I'll show some examples near the end that will show this drift.

MEMBER KRESS: But when you're looking for the bias, are you looking at the time average drift in the data itself? Is that the --

MR. HINES: Now we're actually using data that's not having any drift at all when we're looking for the bias. So we're using good data. We're saying that if I make this model a 1,000 times and I take the average value of my model prediction, then I have to compare that to the de-noised signal itself. And the difference there is going to be an estimate of your bias.

MEMBER KRESS: What's the advantage of wavelets for de-noising over say ordinary -- it seems to me like you could either of them.

MR. HINES: You can use certain filtering technique. A lot of direct filtering techniques that you would use -- actually, there's a paper on the comparison of those two.

MEMBER KRESS: Yes.

MR. HINES: That was done by Argonne.

MEMBER KRESS: Okay.

MR. HINES: And they've determined that wavelet has certain advantages over it.

MEMBER KRESS: Okay. So there is a paper by Argonne? I might want to look at that.

MR. HINES: Yes. Because they called it whitening at first, whitening the data. And they used transformers to do the data whitening.

MEMBER KRESS: Yes.

MR. HINES: And then they use FFT or use wavelets to do the same type of things, and Argonne went with the wavelet technique. So there's a paper I could give you that compares those.

So you have to estimate the true signal to get the bias. And, (a) you have to use that if you want to do Latin Hypercube Sampling because you need to know what the true value is to understand what the noise distribution; (b) you would have to find the true signal to calculate the bias itself. And you can wavelet de-noising, that's what's Argonne's using and Independent Component Analysis is another technique that you can use if you have redundant sensors. It's a couple of techniques that we've investigated and explained what the assumptions are, explain when you can and should not use those.

This is just one of the cases that we ran. It basically shows you that they both give you very similar results. These are kind of relative here. And we're now doing a sensitivity analysis to show that how much error can you have in your de-noising, how will that effect your final uncertainty analysis result. But basically the ICA or the wavelets give you very similar types of results.

This slide is the on the process equipment monitoring toolbox. This is the user manual that goes along with it. It says the user manual, the tutorial and the guide and then a little description and example usages of it.

CHAIRMAN APOSTOLAKIS: Is that that NUREG or--

MR. ARNDT: We haven't decided how we're going to publish it. It'll probably just be a reference report.

MR. HINES: It's our winter 2006 deliverable. So the deliverables, we have three NUREGs and then we have this toolbox. And this toolbox will be used to evaluate the different techniques, all these different modeling techniques are implemented in the toolbox. All the different uncertainty analysis techniques, wavelet, de-noising are implemented in the toolbox.

And then for a third NUREG we're going to go in and look at limiting case studies. If these assumptions aren't completely met, how do they effect the results? And if you start getting outside of your operating condition, does this thing fail? The way it should fail is your uncertainty should just blow up because you no longer have confidence on your model predictions. And does that do that or do you need an additional module that says are we now operating within the limits of our training data? So we're looking at all these limiting case studies for the third NUREG.

MR. ARNDT: And the point of that work is really to give the NRC a technically defendable argument that says if you guys don't do this or if you don't do a good analysis of your error or if you don't have good training data, then we're not going to let you do it until you fix it.

MEMBER SIEBER: It sounds like you got to publish that?

MR. ARNDT: Probably.

MEMBER SIEBER: Yes.

MR. ARNDT: Yes.

MEMBER SIEBER: Otherwise they will have no clue as to what it is you want them to do.

MR. ARNDT: Yes.

MEMBER SIEBER: Could I take a look at that, please, while you're --

MR. HINES: This? Yes, sure.

CHAIRMAN APOSTOLAKIS: And why didn't you make this a NUREG?

MR. ARNDT: That's just the user guide and the tutorial on the tool. And we might. But the

NUREGs are going to be actually the studies that were performed using the tool.

MR. HINES: I think when we originally wrote the statement of work we had these three NUREGs that we defined. And this thing has just continued to grow and be extremely useful. In fact, Kenny Gross when to Sun Microsystems and is doing reliability of their big servers. And he just said, you know, he wants access to this. So he's going to refund a project so he can use these tools.

CHAIRMAN APOSTOLAKIS: Who is this fellow you mentioned twice?

MR. HINES: Kenny Gross is kind of the, I call him -- he's almost a father of these empirical modeling techniques. He was a guy from Argonne. They won a research 100 award with the MSET techniques. This 1995 DOE funded project, they had what they called the shoot-out. Everybody brought their best technique and they had a competition. And Argonne won it with this.

CHAIRMAN APOSTOLAKIS: So where is he now?

MR. HINES: Sun Microsystems hired him. You know, if we have a trip in a reactor it costs you a million dollars, you know, you lost day. If they lose an hour of eBay, that might be $8 million. So they keep going up to the more expensive type of processes.

MR. GUARRO: Do you mind going back to number 15 for a second:

MR. HINES: Yes, sir.

MR. GUARRO: You said that ICA and wavelet gives similar results. I mean, see some of these factors that are similar, some are not. And so why do you say that overall they're similar? I mean, what is relevant here? I'm trying to understand, simply.

MR. HINES: Okay. I can go into a little bit more detail and tell you that some of the ways that the wavelet de-noising -- some of the major rules that they use. Basically at the wavelet de-noising you have these coefficients that you can set and then you have these sensors. And you want to try to remove as much of the variance as possible such that when you remove the variance, the variance that you've removed is not correlated. If you remove the variance and it's correlated, you're probably removing actual plant information.

And so there are a lot of rules like that. So if you look at the second to the bottom it says "expected correlation." This would be the correlation of the noise that you removed. Actually, it basically has a correlation of zero, wavelet finds that out. ICA removes a little bit too much noise.

MR. GUARRO: I was looking at that and I saw those being really different.

MR. HINES: Yes. Well, I'm trying to look at the one that has -- different stuff. Even a correlation .3, you know is limiting of even having any useful information at all. And if you look up at the expected noise variance, this is using some simulated data. So we know what the actual noise variances are, what the variance reduction should be. And you can see that the ICA really filtered a little bit too much. The third from the bottom line says it's the "fractional variance reduction," but it reduced the variance a little bit too much.

So what we see here is that the wavelet is very close to actual and that the ICA removed a little bit too much of the signal.

Now what's the degradation effect of removing a little too much of a noise when you're trying to predict what the true value, which is then used to predict what the bias is? Well, that's what we're doing here in the next few weeks when we're going to do a sensitivity study and show how does this effect the bottom line.

CHAIRMAN APOSTOLAKIS: I guess I haven't really grasped the big picture.

MR. HINES: Okay.

CHAIRMAN APOSTOLAKIS: Wavelet is used at Argonne, is that correct?

MR. HINES: For de-noising the signals to get the true value.

CHAIRMAN APOSTOLAKIS: Yes. And then ICA was developed at Tennessee, your --

MR. HINES: Yes.

CHAIRMAN APOSTOLAKIS: Then why was there a need for that to be developed? Why can't the Agency use the Argonne method?

MR. HINES: They can, but different vendors maybe using different techniques. And these are the techniques that are out there in the literature.

ICA is being used for some additional on-line monitoring techniques.

CHAIRMAN APOSTOLAKIS: So the vendors are using the Argonne method?

MR. HINES: The vendors are really -- and I think this one reason V.C. Summer hasn't stepped up the plate yet. The vendors don't have -- this has been done more in the research field rather than the vendors actually applying this and incorporating it into their products. And I think that's why V.C. Summer is slow to put in this license amendment because they're using Expert Microsystem's product and Expert Microsystem has not finalized the version where they've incorporated these uncertainty analysis modules.

CHAIRMAN APOSTOLAKIS: I guess I'm trying to understand why was there a need to develop ICA?

MR. HINES: ICA is being used for additional things in sensor calibrating monitoring. If I have -- first stage determine pressure where I only have two sensors, if one of those sensors starts to drift, I don't know which ones drifting and which one I should put my control system on, channel A or channel B. ICA can be used to determine what's the process portion of those variables and what's the drift of those variables. And if you give me two sensors, I can tell you which one is drifting and which one's not. That's some research that EPRI funded.

So it's been a technique that's been looked at for de-noising because it has these good properties of being able to pull out noise components and process variable components from redundant sensor data. So that's why it's being studied.

MR. ARNDT: Let me answer the question differently. This project didn't develop this methodology. This project is designed to figure out what's out there, what can licensee choose to submit to us --

CHAIRMAN APOSTOLAKIS: So you had already developed ICA?

MR. HINES: ICE was developed and used by EPRI four years ago.

CHAIRMAN APOSTOLAKIS: Oh, I'm sorry.

MR. HINES: And then used by TVA, had a follow on product to use to ICA.

CHAIRMAN APOSTOLAKIS: But the reason why I confused is because slide 14 does ICA mean Independent Component Analysis?

MR. HINES: Yes, sir.

CHAIRMAN APOSTOLAKIS: Then there's parenthesis (Ding UT).

MR. HINES: Yes. He graduated about two years ago. He's one of my Ph.D. students.

CHAIRMAN APOSTOLAKIS: Right.

MR. HINES: So he applied the ICA techniques --

CHAIRMAN APOSTOLAKIS: Oh, he applied the

ICA? He didn't develop it?

MR. HINES: Well, ICA it's like the principle component so that's already been developed.

CHAIRMAN APOSTOLAKIS: Oh.

MR. HINES: But the application to sensor calibration monitoring was new.

CHAIRMAN APOSTOLAKIS: Okay.

MR. HINES: These are the main functions that you need to build these empirical models, and they're the functions that are incorporated.

Okay. So for example, one of the vendors, Sure Sense, is the software product that was used by these six different in this EPRI implementation plan. You know, they do data manipulation, so they have different algorithms for outlier detection and correction. You need to train the models on good data. Model development is how do you determine which parameters to put in a model so they have to be highly correlated variables.

Then the prediction, the autoassociative kernel regression is what Smart Signal uses. Autoassociative MSET is what Sure Sense used. Autoassociative MSET is the company in Chicago. And autoassociative neural networks in the Holland Reactor Project. So the three models were chosen because that's the three things that have been used in the EPRI implementation plan, was the three techniques that have been used out there. So the ones we really need to know about.

Model performance evaluation is how the performance metrics that are being used to judge how well a model can predict.

The uncertainty estimation is something that the vendors are really a little bit slow in incorporating into their systems, but they know they must. And there's been a lot of research by Argonne and others in those areas.

And then the fault detection is how do you determine when your sensor has drifted enough that it doesn't meet your requirements anymore. You need to either schedule for calibration or there could be a different limit that says you need to take it out of service and consider it failed.

MR. ARNDT: So for example if we get an applicant that is using a particular methodology and a particular set of data and a particular uncertainty analysis, we can then just plug in these models.

MR. HINES: Yes. And we will have already studied these and we'll know what the assumptions are and what you need to look for when these different techniques are being applied.

MR. WATERMAN: This is Mike Waterman speaking from -- I'm detailed to NRR right now, so I can speak for NRR.

When you say you're looking for what they should be doing and things like that, is part of this project going to provide NRR with acceptance criteria so that when a model comes in they actually have some subjective acceptance criteria they can use to approve or disapprove, disapprove if you will, or at least to recommend that the licensee go back and do a little bit better job?

I understand it's good to know how the models are used, from a regulatory perspective what's also important is that we know where to draw the line. Is that also part of your project?

MR. HINES: I understand what you're saying. It's almost that the line gets drawn by itself. If they properly apply these techniques, and we'll say has to be done to apply these techniques so there's some criteria there, but then is the model uncertainty small enough that it's actually going to be useful to them? That's why I said the line almost gets drawn by itself.

MR. WATERMAN: Yes.

MR. HINES: But there will be certain criteria. If you do this, you need to use these techniques and you need to verify that this is true by using techniques.

MR. WATERMAN: Yes. Yes. Because usually when we get a submittal, you look at the submittal from the license and you're almost guaranteed to see where they meet all the criteria.

MR. HINES: Right.

MR. WATERMAN: And it falls on the regulator to figure out whether or not they did that correctly enough to take credit for that.

MR. HINES: Right.

MR. WATERMAN: So I guess that's what I was looking for from a regulatory perspective is how do I go about doing that independent assessment. And I guess that's what you're telling me.

MR. HINES: And that's really the goal of the whole product.

MR. WATERMAN: Okay.

MR. HINES: The whole project is to give the regulators to the tools. The first NUREG says where do you go to find this information. There's ten years of literature out there. You know, you have 14 requirements. What literature corresponds to what requirements and where do you go and how do you learn these things. So that's kind of a quick reference manual.

The second NUREG says okay now we're going to tell you how all these models work, what you need to do, how the uncertainty analysis techniques are.

The third is here's all these limited case studies. When you apply it, these are things you need to look for. Did they do this, did they do this and did they do this.

So we're trying to meet your needs and how you've got to regulate this.

CHAIRMAN APOSTOLAKIS: Does the regulatory staff rely on NUREGs or eventually all these lessons will have to be in a different document for the reviewer? Ultimately, I guess SRP will have to have some advice.

MR. WATERMAN: This is Mike Waterman again.

What the regulatory -- the regulatory staff when we say an application is acceptable, we can't say it's acceptable because it says so in the NUREG.

CHAIRMAN APOSTOLAKIS: No. No. I understand that.

MR. WATERMAN: The NUREG is kind of toothless with respect to that. So generally we need to go from the NUREG into the regulatory space and say this guidance falls within this regulation because. And because it falls within that regulation and these are the acceptance criteria and we can tie those back to regulations, we can then say it is acceptable. But just to have a NUREG by itself isn't generally enough to license anything. The NUREG is background.

CHAIRMAN APOSTOLAKIS: And you do that via regulatory guides?

MR. WATERMAN: Yes, we do. Reg guides or we --

CHAIRMAN APOSTOLAKIS: And ultimately there will have to be a regulatory guide where the essence of the research will be?

MR. WATERMAN: Or something anyway that can link into a regulation directly. So you can this is not acceptable per GDC 24, for example.

CHAIRMAN APOSTOLAKIS: Yes, I understand.

MR. ARNDT: And it's very much case specific. In this case it's a fairly narrow kind of application so it probably wouldn't be a reg guide. In this case one way to do it would be to go back to the original generic SER and the 14 points that are necessary to be acceptable for a case specific application. And appropriate application of uncertainty estimation is one of the things that is required.

CHAIRMAN APOSTOLAKIS: Yes.

MR. ARNDT: So that could be the link.

CHAIRMAN APOSTOLAKIS: Because, you know, it just struck me that to say that we will have three NUREG reports and they will have the information, I can't see a reviewer of NRR, you know having three reports in front of him and saying, you know -- there must be some other document --

MR. ARNDT: Yes.

MR. ARNDT: -- that will summarize what's relevant. But that's a regulatory thing, it's not your job, I say that.

MR. ARNDT: The point is whether it's a NUREG or a report or a whatever, the information and the acceptance criteria and what's acceptable and what's not acceptable and how you go about calculating what's acceptable and what's not acceptable.

MR. HINES: At the very end of these NUREGs there's a section called "Challenges." And these are basically one paragraph things that these are the things that you really need to worry about.

CHAIRMAN APOSTOLAKIS: But you have to understand, that the regulatory staff doesn't want to be challenged. They want to know what to do.

MR. WATERMAN: No. They want to challenge the licensee.

CHAIRMAN APOSTOLAKIS: They are very different objectives. You can say challenges, you know.

MR. HINES: Yes.

CHAIRMAN APOSTOLAKIS: Because you are an academic.

MR. ARNDT: Let's go for it.

MR. HINES: Okay. Some different methods of detecting linear drift has become significant. This is the error uncertainty limit monitoring. Let me show you on the next slide.

Basically this is an example of where we'd have a residual, which is the prediction error. The error between our prediction and our measurement. So this is like our residual. And this shows here's our residuals going along and there's our uncertainty measurements going along. When that 95 percent confidence interval of that uncertainty measurement crosses that tolerate, that drift limit then you have to say, you know, I have a problem.

And the way the industry is looking at it, they have two different limits. One limit says okay, we need to go look at it and put it on our calibration schedule. And the other limit says this thing does meet our requirements anymore. It should be taken out of service, declared inoperable. So this is one method of doing the drift detection.

Another method that's been used by Argonne Labs called the SPRT, the sequential probability ratio test, rather than kind of doing an average, this is a technique that determines where the greater probability is that this residual train has come from. This distribution that has a mean of zero, meaning the residual hasn't drifted or this other distribution that has a mean of let's say, 1 percent saying that it has drifted. So it's a statistical technique that determines from incoming train of residuals what the probability is that it comes from an unfaulted mean distribution or a distribution that has some faulted mean. And this is an example of our residual growing with time and then a fault hypothesis. It's a powerful technique that was developed by Wald back in 1947.

Okay. So conclusions. We've turned in one NUREG. The second NUREG's been turned in in a draft form. The toolbox will be turned probably in December.

CHAIRMAN APOSTOLAKIS: How long have you been at it? How long have you been doing this?

MR. HINES: A year.

CHAIRMAN APOSTOLAKIS: I mean for the NRC, for the Agency?

MR. HINES: August last year. August last year. So a little over a year and two months.

CHAIRMAN APOSTOLAKIS: So you're in your second year right now?

MR. HINES: Yes. We turned in our second, and then the third will be turned in at the end of next summer.

CHAIRMAN APOSTOLAKIS: Do you have any students involved in this?

MR. HINES: Yes, two students. Yes, I didn't do this all myself. Yes. A lot of work and I have two really good graduate students.

MEMBER SIEBER: And they won the football game?

CHAIRMAN APOSTOLAKIS: What?

MEMBER SIEBER: They won the football game, too.

CHAIRMAN APOSTOLAKIS: Wonderful.

MR. HINES: No, my students aren't playing on the football team.

So the second NUREG is basically the analytical and theoretical study, the methods to predict bias and variance, an analysis of the methods and also development of some enhancements to what's already been developed out there.

Derivation and application of analytical uncertainty estimation techniques.

Comparison of bootstrap and Latin Hypercube Sampling techniques, comparison of wavelet and ICA and other types of de-noising techniques.

And then the PEM toolbox, PEM standing for process and equipment monitoring toolbox developed that incorporates all the major algorithms that the vendors have.

Also in this second part where we're doing the limited case studies, we're not only using or toolbox, but we have compiled a code for the models from both Smart Signal and from Expert Microsystems. So we're going to compare what their compiled -- because they don't want to give you the actual source codes. I don't want it anyway because it has IP, it's important to them to keep that secret. But they've told us what the algorithm uses and we can compare that with our implementation of the algorithm and compare and see do their tools give you the results that we would expect? And so far the early results there is they give us exactly the same. You know, there's a little bit of random uncertainty, you know, as always then they use Monte Carlo techniques. But they perform exactly as expected.

MR. ARNDT: Which is important because we're going to use this as a tool to evaluate their methodologies.

CHAIRMAN APOSTOLAKIS: Right.

MR. ARNDT: We got to have the tool that is giving us the right answer and not giving us problems.

CHAIRMAN APOSTOLAKIS: Thanks.

MR. WATERMAN: So, Steve, this is Mike Waterman again now from Research. So what you're saying is that if we have the toolbox, we should be able to go a licensee and say send us all of your data that you used. And then we take their data and run it through our own toolbox and say, ah, looks like you did good. So we have some level of confidence that you correctly applied the techniques or we'd come back and say "Well, we noticed that we have more bias here, more variance than what you stated you would have."

Is that is what is foreseen for the use of the toolbox?

MR. ARNDT: Yes. It gives us the opportunity if we want to structure the review that way. And we can structure the review in a number of different ways. But if we have to reason to believe where we want to do an independent test of the uncertainty analysis, for example, we can get the data, their training data and use this tool to convince ourselves that the bias or the whatever uncertainty prediction is what they're telling us it is.

MR. HINES: Yes, I think you could do that. I'd be surprised if that was actually done. I think through the second phase we would come through and we would have confidence that their tools work as designed and we would look at the linear bias studies and almost have their tools validated that way. I mean, I'm not a regulator, but I would think to have a regulator completely understand all of this to such a detail; I mean it's all there. But it gives us -- that's a lot of material for someone to read and understand and go out and apply. But you would have the option to do that.

MR. WATERMAN: Yes.

MR. ARNDT: What we're going to have is we're going to have the limiting case studies which allow someone to look and say all right, these the particular areas you're going to get yourself in trouble with. So you can look at it from that standpoint.

We're going to have the generic technology issues that allow you to reference and ask specific questions.

And we're going to have the tool that if you want to go to that extent, you can actually go out and validate the technology.

MR. WATERMAN: Yes. I was looking at it sort of from the perspective of Reactor Systems Branch, a licensee comes in with a new correlation or whatever. And they show their analysis reads such-and-such a point. Well, Research Systems Branch goes ahead and plugs that model into RELAP5 and comes up with their own conclusions and checks their conclusions against what a licensee or a vendor conclude.

MR. HINES: That's right. This is --

MR. WATERMAN: And I was sort of looking at this as a similar type of application where the licensee comes in and says this is the model we used, and here's the data and this is the result and therefore you can license it. And we take the toolbox and we say we're going to do an independent analysis.

MR. ARNDT: Yes. This is entirely analogous to that.

MR. WATERMAN: Okay.

MR. ARNDT: And it's just like anything else, it's a workload, staffing, how much effort do we want to put into it decision.

MR. WATERMAN: Okay.

MR. ARNDT: But we have the capability to do so.

CHAIRMAN APOSTOLAKIS: That's it?

MR. ARNDT: That's it.

CHAIRMAN APOSTOLAKIS: Thank you very much. Thank you.

MR. HINES: Thank you.

CHAIRMAN APOSTOLAKIS: What I would like to do now is give some advice to the staff regarding the November full Committee meeting, what we would expect to see. And then go around the table and see what kind of advice you will be giving me in drafting the letter.

Well, let me start this way, Bill, what is it that you will be asking us to do in November? You will request a letter?

MR. KEMPER: Yes.

CHAIRMAN APOSTOLAKIS: Saying what?

MR. KEMPER: Saying that you think that this is a good research program.

CHAIRMAN APOSTOLAKIS: And advising the EDO that he do what? I mean, do we just say it's a good program and don't usually advise them to do something?

MR. THORNSBURY: For example, if you were going to be sending it to the Commission, we would say okay, we think it's ready to go to the Commission or is it going to be sent or issued?

MR. KEMPER: No. We don't intend to send this to the Commission. This is different than we did last time. Just a management decision. And in RES Carl Pepperello intends to issue it under his signature to the other office directors and copy the Commission. But we are hoping that the ACRS will endorse this as meaningful, worthy research that Agency resources should be expended to provide to the Staff.

MR. ARNDT: And if you have any comments on or input on priorities or resources or anything like that, we would be interested in hearing.

CHAIRMAN APOSTOLAKIS: Just wondering. I mean, what exactly would the recommendation be?

What did we say in the human liability? Do you remember? Does anybody remember?

MR. KEMPER: We've been through this once before. We can pull the memo what happened with the previous search plan that you all approved back in 2000.

CHAIRMAN APOSTOLAKIS: Because I don't remember a case where the letter says you know, this is a good thing, live with it. I mean, we don't do that. We have to say something that the EDO has to do something. Now it may be what you said, Bill, that this is a plan that now can be implemented and go ahead.

MR. KEMPER: Right.

MR. ARNDT: We're check.

CHAIRMAN APOSTOLAKIS: Sorry.

MEMBER SIEBER: We could write a letter to--

CHAIRMAN APOSTOLAKIS: You have to be closer to the microphone.

MEMBER SIEBER: You could write a letter that had the conclusion that the research plan is appropriate to meet Agency needs.

CHAIRMAN APOSTOLAKIS: That is a very good point. Yes.

MEMBER SIEBER: Even without a recommendation.

CHAIRMAN APOSTOLAKIS: And leave it at that?

MEMBER SIEBER: Yes.

CHAIRMAN APOSTOLAKIS: Yes, that's a good point.

Anyway, we'll check back letters and see how it is done.

MR. KEMPER: Yes.

CHAIRMAN APOSTOLAKIS: Now, what advice should we give the Staff regarding the presentation?

MEMBER BONACA: One comment had, yes, and I would like to repeat. I mean, to me I think it is a good plan. I am very appreciative of the plan because I think it gives also a coherent summary of all that you're planning to do. There is information that you do have about the challenges, examples of the challenges, I mean in the field. To the degree to which you can provide them, it gives further imports to the need for the work. In some cases, it really makes it -- you know, you get an understanding of how this new technology that is being implements all over the place, it's representing a challenge right now. I think that would be useful to the Committee.

MEMBER KRESS: How much time do we have on this?

CHAIRMAN APOSTOLAKIS: An hour and a half.

MEMBER KRESS: That's not much time to do a lot. We need to focus that time on the actual plan itself.

CHAIRMAN APOSTOLAKIS: That's right.

MEMBER KRESS: And I don't --

MEMBER BONACA: Well, I wasn't proposing an extensive, you know, but whatever you have some examples that you can fit there, that's all I meant.

CHAIRMAN APOSTOLAKIS: Yes. I think you have to start at a high level.

MEMBER KRESS: Yes.

CHAIRMAN APOSTOLAKIS: Because some of the members have not been exposed to this. You know, why is there a need for a plan? What is the plan trying to achieve? What does it --

MEMBER KRESS: Yes, and what's in the plan.

CHAIRMAN APOSTOLAKIS: Yes.

MEMBER KRESS: Get down to that level.

CHAIRMAN APOSTOLAKIS: How does it meet --

what needs of the regulatory function of the Agency are we going to meet after we implement this plan.

MEMBER KRESS: Right.

CHAIRMAN APOSTOLAKIS: I tried to capture some of that yesterday.

MEMBER SIEBER: It seems to me that you ought to start off by describing how this part of the industry is changing and that it applies to, perhaps, advanced reactors, new reactors and replacements. And so the --

MEMBER KRESS: Yes. That's to the context. I think that's a good idea.

CHAIRMAN APOSTOLAKIS: I would start with the replacements.

MEMBER SIEBER: And then you'd need to describe how's the Agency going to react to this.

MEMBER KRESS: Right.

MEMBER SIEBER: In other words, people are going to submit applications. You might even want to spend two minutes on 5059 probably is good enough to approve this stuff in plants. And what those applications are likely to contain. And what are the challenges for the Staff for reviewing and approving those.

CHAIRMAN APOSTOLAKIS: Exactly. Exactly.

MEMBER SIEBER: Then you go to the research plan and say we're developing these tools to get ready for this new adventure.

CHAIRMAN APOSTOLAKIS: Yes. Yes.

MEMBER SIEBER: And then draw some conclusions it's a wonderful plan, we're going to be all prepared. Even if it costs double, it would be worth it.

CHAIRMAN APOSTOLAKIS: Now as I recall you are talking about the six areas, aren't you?

MR. ARNDT: Yes.

MR. KEMPER: Yes. Five, actually.

CHAIRMAN APOSTOLAKIS: I think that you would be useful if you justified in that high level context why did you decide that these six areas are a problem. What needs are they going to meet? Okay. If the tools that will be produced and whatever methods are produced, will be produced from these six areas, why these six and not another set? Why not four? You know, that I think is what the Committee expects to see from a plan. That we are fundamentally -- the fundamental question is what Agency needs are you going to satisfy if you implement this. This is the fundamental question.

Now, as Jack said, you know you start by setting in context and so on. But don't forget the fundamental question. We are doing something, we are expending resources to meet Agency's need.

MEMBER KRESS: I think there would be certain members of the Committee that would love to hear that presentation we just from the University of Tennessee. But, unfortunately, you're just not going to have it. That would eat up the whole time.

MR. ARNDT: No, we're not going to --

MEMBER KRESS: Somebody with the EMI and--

MR. ARNDT: Right. The point of ding it here is to give you some feel of where we're going on certain programs to understand. But the presentation for the Committee --

MEMBER KRESS: Just cannot get that detailed.

MR. ARNDT: -- will be a high level of relatively little level of detail. But I think we can structure in such a way that it goes to why we're doing things, how we're doing things. In some cases it's to meet immediate needs, in some cases to get ready for things.

MEMBER BONACA: That was my comment, by the way, that Jack actually verbalized much better. The need for context, however, is important. Because this is my opinion. I've attended a number of these presentations and they have been all high level. Too many statements about we will do this and this, which presume a level of understanding of the issues in the field, the problems, the challenges there are. I think part of the Committee would be lost in that very high level.

MEMBER SIEBER: I think so, too.

MEMBER BONACA: And to the degree to which you can frame the environment we're living and what we are facing, I think this would be helpful.

CHAIRMAN APOSTOLAKIS: And also some of the stuff that you have in the appendices in the report, you know the privatization and all that. I think that's good stuff. You should bring it up front. I mean, that you have attempted to prioritize; you use a particular method, as you say in the report, you know, these are the factors that influenced our decisions.

MEMBER KRESS: I wouldn't go into great detail on that.

CHAIRMAN APOSTOLAKIS: No detail. But how show that you have done it.

MEMBER KRESS: Yes, show that you have done it.

MEMBER SIEBER: One of the things that made these last two days interesting for me is there a mixture between the high level and the practical things.

MR. ARNDT: Right.

MEMBER SIEBER: And if we act like regulators and stick at the high level, philosophical precepts and so forth, it's going to be very uninteresting presentation. I think you need to retain the mix that's actually built into the research plan into your presentation of it. The same kinds of things that you did during this last two days.

MR. ARNDT: Okay.

MEMBER SIEBER: And, you know, that keeps people interested.

MR. ARNDT: It'll be challenging, but we'll see what we can do.

MEMBER SIEBER: Yes. And here's the philosophical approach and here's the hardware application and these are the kinds of folks who are likely to employ it, and here's the decisions that we're going to have to make.

MR. ARNDT: Yes. I think we can probably work some of that into maybe a thread example throughout the issue based on one of the current applications or something like that.

MEMBER SIEBER: Right.

MR. ARNDT: Or data, computational results.

MEMBER SIEBER: Oconee would be an example.

MR. ARNDT: Oconee or --

CHAIRMAN APOSTOLAKIS: How you do it is entirely up to you.

MR. ARNDT: Okay.

CHAIRMAN APOSTOLAKIS: We're just telling you what kinds of issues or questions --

MR. ARNDT: Okay.

MEMBER KRESS: I think this time we could do without the EPRI presentation of it, too.

MR. ARNDT: Yes.

CHAIRMAN APOSTOLAKIS: You think so?

MEMBER KRESS: I would think so.

MEMBER SIEBER: Well, that issue isn't solved yet, at least in my mind.

MR. ARNDT: No. That's an open issue.

MEMBER SIEBER: And so it's interesting but fails to --

MEMBER KRESS: That one will come back to us, I think.

MR. ARNDT: Oh, yes.

CHAIRMAN APOSTOLAKIS: And, yes, I mean we will have other opportunities to review individual projects as they are progressing or completed. So the Committee will come back to it. But right now we're focusing on the plan.

MR. ARNDT: Yes. And I think the big issue not only is the plan itself, but the program that it's putting forth. So really what we want the Committee to be able to comment on is the program sound and is the plan for the future the right direction.

MEMBER BONACA: Yes. The fact is, you know, as you all recall back in May we presented or we tried to present the entire plan in a fair amount of detail. So much so we didn't get through the presentation. But any rate, that information wasn't made available to the Committee. So I'm hoping that we can bank on some of that memory still being there, if you will, or familiarity still being there with the plan. I mean, we could just redo that, but I don't know --I'm hoping that from this time since we've had this interaction with you all, we can go to a higher level, though. Albeit I respect what you're saying, you know, but if we get mired down too much and we talk about wavelet de-noising, you know what happens there. We'll end up getting all tangled up and we'll never get through.

CHAIRMAN APOSTOLAKIS: Yes. I would agree with that. I believe the six areas that you have identified must be justified and discussed.

MR. ARNDT: Yes.

CHAIRMAN APOSTOLAKIS: And then maybe list the projects under each one or without really going into detail.

MEMBER BONACA: Yes. That's kind of what I was thinking. Right.

CHAIRMAN APOSTOLAKIS: Because there's no time to do that.

MEMBER BONACA: Right. Exactly. Just an hour and a half, and it goes very fast.

CHAIRMAN APOSTOLAKIS: Because even with their committees, you know, one member who is not a member of the Subcommittee can always raise any question he wants and he expects to be convinced.

MEMBER SIEBER: And he will.

CHAIRMAN APOSTOLAKIS: I mean, we cannot say but you know we said that in May. That's the way things are.

MEMBER SIEBER: And he will.

CHAIRMAN APOSTOLAKIS: Huh?

MEMBER SIEBER: And he will.

MR. GUARRO: Perhaps you can use in each area an example of a project that reflects some of your criteria for high priority and just show that.

CHAIRMAN APOSTOLAKIS: It's up to you.

MR. ARNDT: We could present something like this or alternatively this one, which basically has got the same information in a slightly different format.

CHAIRMAN APOSTOLAKIS: Figures area always preferable.

MR. ARNDT: Yes.

CHAIRMAN APOSTOLAKIS: Right, figures are always preferable. Because remember, you are also talking at the same time.

MR. ARNDT: So we can present it at this level.

MR. GUARRO: Sure. Because they are this level.

MR. ARNDT: Because it tells us what we're doing, it's nice color coded. The green is what is currently going on and the yellow has got future projects.

CHAIRMAN APOSTOLAKIS: And you will have already justified the --

MR. ARNDT: Right. We will previously discuss --

CHAIRMAN APOSTOLAKIS: The current event will have been justified.

MR. ARNDT: Why we have these particular--

MEMBER BONACA: So you will also discuss what's already going on and what is the plan for the future.

MR. ARNDT: Right.

MEMBER BONACA: Which is also, that's very important. Because I mean this is a time also where we're putting it together -- I think this is information is extremely useful.

CHAIRMAN APOSTOLAKIS: But, again, you might questions like at the end of the day, so to speak, or at the end of the decade what is it that you will produce? Are you going to make the review process more efficient? Are you going to enhance the technical basis so it will be more effective? But, again, if you leave it at that high level, people are not convinced.

MR. ARNDT: Yes.

CHAIRMAN APOSTOLAKIS: I mean, you have to have examples.

MR. ARNDT: I think doing examples I think is the only practical way of doing this. Is taking two, three, four -- however many the time allows and talking through specific examples.

CHAIRMAN APOSTOLAKIS: Okay. Great. Did we exhaust the subject?

MEMBER KRESS: I think so.

MEMBER SIEBER: I'm exhausted.

CHAIRMAN APOSTOLAKIS: Let's go around the table and I want you guys to give me some advice as to what you would expect to see in the letter.

Now, Sergio, you're going to also send me something in writing, right?

MR. GUARRO: Yes.

CHAIRMAN APOSTOLAKIS: Okay. Mario, you have already expressed an opinion.

MEMBER BONACA: I already expressed the opinion.

CHAIRMAN APOSTOLAKIS: Which is?

MEMBER BONACA: I think it is a good plan. And I think we -- you know, at this level we're not going to comment on individual tasks.

CHAIRMAN APOSTOLAKIS: No.

MEMBER BONACA: I mean, that's not the point. The point is that I think it's a comprehensive view of what the situation is and the challenges that I think NRR is going to face in the future. I think there is sufficient consideration of users need, and that's an important element that we always question.

CHAIRMAN APOSTOLAKIS: Very good.

Sergio?

MR. GUARRO: Well, I don't have much more to add. I think I agree with what Mario just said. I think I was impressed by, you know, how comprehensive this is. And I think it'll be a very good plan to execute. There are challenges in the execution I think, but --

CHAIRMAN APOSTOLAKIS: Okay. Very good.

Tom?

MEMBER KRESS: Gee, I make it unanimous. I was impressed. It was a very good plan. And --

CHAIRMAN APOSTOLAKIS: I haven't seen so many impressed people in my life.

MEMBER KRESS: You don't often see plans that are this well thought out and this comprehensive.

MEMBER SIEBER: You aren't done asking everyone.

MEMBER KRESS: Yes. And I'm also impressed that you got good people working on it, too.

CHAIRMAN APOSTOLAKIS: Except the

University of Tennessee guy. I don't know about him.

MEMBER KRESS: That's an automatic --

CHAIRMAN APOSTOLAKIS: We don't want to give too much credit to the University of Tennessee.

MEMBER KRESS: At the University of Tennessee they're automatic. Okay.

CHAIRMAN APOSTOLAKIS: Mr. Sieber?

MEMBER SIEBER: I'm worried. Okay. And I think that NRR and Research are looking in the crystal ball trying to see what the future is. And out there there are people who are coming up with physical needs for new instruments and controls. We have not too much of a clue as to what they are going to put in, whether it's going to be a wholesale thing or just change it out piece by piece. And anyone who is bought personal computers recognizes that the day after you buy it it's obsolete and that there are so many CPU chips out there of different types and different languages and service pack after service pack after service pack; it's going to be very difficult to review all of this.

And so the question is when we look in the crystal ball, are we picking the right things to direct our money at? And so if I were to question anything at all, I would question are these the right tasks? And I'm not sure that we as ACRS can come up with any better answer than the Staff can come up with. But I think we need to somehow, at least personally I have to look at and address that issue so that I'm convinced that these are the right things to do. And I think that we would write a really good letter if we were all convinced and would say these are the right things to do based on what we know today. But otherwise, I actually do think they're the right things to do. Yes, but on the other hand, I don't have a basis yet

CHAIRMAN APOSTOLAKIS: That's why I mentioned that I really insist that you really have to justify the six areas.

MEMBER SIEBER: Yes.

CHAIRMAN APOSTOLAKIS: And you have to spend some time on it and say after you do the other things like the context and how we serve the agency and all that, why these --

MEMBER SIEBER: Why these?

CHAIRMAN APOSTOLAKIS: --and not something else.

MEMBER SIEBER: Yes.

CHAIRMAN APOSTOLAKIS: Why are they fairly complete based on what the community knows right now.

I mean, you know, if something comes up three years from now that nobody has thought of, nobody will blame you. But we don't want somebody right now to say but you missed this big thing. So you have to convince the Committee, I think, that these are the good areas that cover -- you have done as good a job as anybody could under the --

MEMBER SIEBER: Right. In summary, that's what I've been thinking about in preparing for this meeting and hearing the meeting; are these the right things to do.

MEMBER BONACA: Although, I mean, I got the sense that it's comprehensive. It seems to me that I would be more concerned about they have too much in the fire than too little. Maybe, I'm just -- I don't know enough to say that I'm missing certain things.

MR. ARNDT: Yes. And that is always a challenge in research plans, as you all know.

CHAIRMAN APOSTOLAKIS: But that's the importance of prioritize.

MR. ARNDT: It is. That's right. And it's both a prioritization between individual topics, it's a prioritization between today needs versus tomorrow needs. It's a prioritization on how much time you spend looking and how much you time spend doing. So there's a dimensions to that, and we'll try and address that as best we can.

MR. GUARRO: You also have a timetable for implementation. I mean, you are planning for 2006/2007. So you have time to get to a closer horizon and make decisions on whether you should just drop something and do something else?

MR. ARNDT: Right. And we plan on doing that with a yearly update.

MEMBER SIEBER: By the way, the person to answer the question are these the right things is NRR. Do they want to include a few minutes for NRR reviewers to say does this work, here are the tools are need.

CHAIRMAN APOSTOLAKIS: Like we had Mr. Loeser, is that his name?

MR. ARNDT: Yes.

CHAIRMAN APOSTOLAKIS: He gave some pretty good answers the last day.

MEMBER SIEBER: So you may want to do that. That was compelling for me.

CHAIRMAN APOSTOLAKIS: Yes. And maybe NMSS, too.

MR. ARNDT: Yes.

CHAIRMAN APOSTOLAKIS: Those are the two decision makers, right?

MR. ARNDT: Well and NCR.

CHAIRMAN APOSTOLAKIS: Oh, speaking of that, are we going to say anything about the security plan? Can we say anything?

MEMBER SIEBER: No. We were supposed to forget all about that.

MEMBER KRESS: Well, obviously we'll have to cover that as one of the areas, you know. So we can provide a lot of information without the STI and the security part.

CHAIRMAN APOSTOLAKIS: So how the Committee then express a view if they haven't seen the more detailed?

MR. ARNDT: Well, the can take the lead from the Subcommittee if you'd like.

MEMBER KRESS: We can't explain to them in detail why we think this is so important --

CHAIRMAN APOSTOLAKIS: So the letter should address everything then.

MEMBER SIEBER: Yes.

MEMBER KRESS: Oh, yes, definitely. Security is a major component of the Research plan.

CHAIRMAN APOSTOLAKIS: Okay. So NSIR

should be here as well?

MEMBER SIEBER: I think anybody that's been on the Internet a few times understands what security means and why it's important.

CHAIRMAN APOSTOLAKIS: Okay. Is there anything else.

MR. WATERMAN: Well, Dr. Apostolakis, Research is taking a lot of kudos for a good research plan. I'd like to point out that that plan has been migrating into the plan it is now in part because NRR provided a lot of comments, maybe they didn't agree with the things we had. But those comments we tried to address those comments anyway. And as a result, I think the plan improved because of comments from NRR and NMSS and NSIR. So I think we ought to give them some credit for the structure of the plan.

MEMBER BONACA: Well, that's why the message has to recognize that, because at least I recognized it. I mean that would be a question that the Committee members will raise. Is the customer satisfied with that and their participation, that has to be communicated.

MR. KEMPER: And I'd like to just make a statement before we close, too. As I said at the outset of this meeting, I really appreciate you alls participation and the time that we've been able to spend with you. I guess this is like the second day and a half session here. So we've spent a lot of time. But we really appreciate the valuable insights that you give us. And I look forward to interacting with you on many more of these projects in the future over the next, who knows.

CHAIRMAN APOSTOLAKIS: Very good. Thank you very.

So I'd like to thank the presenters, all of the them, and the participants. And with that happy note, we are adjourned.

(Whereupon, at 11:49 a.m. the Subcommittee was adjourned.)