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Digital Instrumentation and Control
Subcommittee

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

October 21, 2005

The contents of this transcript of the proceeding of the United States Nuclear Regulatory Commission Advisory Committee on Reactor Safeguards, taken on October 21, 2005, as reported herein, is a record of the discussions recorded at the meeting held on the above date.

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

1 UNITED STATES OF AMERICA
2 NUCLEAR REGULATORY COMMISSION

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4 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)
5 DIGITAL INSTRUMENTATION AND CONTROL SUBCOMMITTEE
6 MEETING

7 + + + + +

8 WEDNESDAY,

9 OCTOBER 21, 2005

10 + + + + +

11
12 The meeting was convened in Room T-2B3 of
13 Two White Flint North, 11545 Rockville Pike,
14 Rockville, Maryland, at 8:30 a.m.

15 MEMBERS PRESENT:

16 GEORGE E. APOSTOLAKIS, Chairman
17 MARIO V. BONACA ACRS Member
18 THOMAS S. KRESS ACRS Member
19 JOHN D. SIEBER ACRS Member

20 ACRS STAFF PRESENT:

21 ERIC A. THORNSBURY, Designated Federal Official

22
23 ACRS CONSULTANTS PRESENT:

24 SERGIO B. GUARRO
25

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1 ALSO PRESENT:

2 CHRISTINA ANTONESCU

3 STEVEN ARNDT

4 PAUL EWING

5 WES HINES

6 BILL KEMPER

7 KOFI KORSAN

8 PAUL LOESER

9 THUY NYUGEN

10 RAY TOROK

11 MIKE WATERMAN

12 RICHARD WOOD

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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 Thornsby is the designated federal official for this meeting.

The rules for participation in today's

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

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

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

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

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

16 MR. ARNDT: Thank you.

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

19 MR. KEMPER: Yes. Thank you, Steve.

20 This is Bill Kemper.

21 We're going to present one of our last
22 sections of the research report, Section 3.5 which
23 deals with emerging technology. And in conjunction
24 with that we have a couple of ongoing projects which
25 we thought would be of interest to you, and we'd

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1 really like to get your insights on that. So that's
2 why we've chosen these particular topics to present
3 those to you. Okay? Thank you.

4 Go ahead, Steve.

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

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

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

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

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

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

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

25 The idea basically having an emerging

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

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

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

17 MS. ANTONESCU: There is.

18 MR. ARNDT: There is in some cases.

19 CHAIRMAN APOSTOLAKIS: Okay.

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

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

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

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

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

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

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

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

23 We have a program that's going to probably
24 start on '07 or '08 to look at applications specific
25 ICs, basic and build programmable beta rays. These

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1 are methodologies to do specific hardware solutions at
2 a lower cost and a lower production run than specialty
3 chips. And there's several people in the world
4 nuclear environment that are very, very interested in
5 this area. Toshiba is working very extensively in the
6 build programmable beta ray arena. And from the
7 preliminary indications they may be coming in next
8 year, as early as next year with an application. So
9 there's a lot of issues in this area.

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

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

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

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

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

7 MS. ANTONESCU: Thank you, Steven.

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

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

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1 becoming informed of emerging I&C technologies and
2 applications in a timely manner.

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

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

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

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

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

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1 and just identify --

2 CHAIRMAN APOSTOLAKIS: Why?

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

5 CHAIRMAN APOSTOLAKIS: And why?

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

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

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

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

25 MS. ANTONESCU: Right.

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1 MR. KEMPER: Yes, but --

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

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

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

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

16 CHAIRMAN APOSTOLAKIS: Yes.

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

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

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1 MS. ANTONESCU: Right.

2 CHAIRMAN APOSTOLAKIS: Just saying
3 research needs is not --

4 MS. ANTONESCU: I understand now.

5 CHAIRMAN APOSTOLAKIS: Yes, sir?

6 MR. KORSAH: This is Kofi Korsah.

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

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

17 MS. ANTONESCU: I will --

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

20 MS. ANTONESCU: So our first report was
21 published in 2003, NUREG/CR 6812. It presents
22 findings and specific technology focus areas. And we
23 came up with eight areas on sensor and measurement
24 systems, communications media and networking,
25 microprocessors, computational platforms, diagnostics

1 and prognostics, control and decision, human-system
2 interactions and high-integrity software. So those
3 areas chosen because they cover a full scope of I&C
4 technology in nuclear power plants.

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

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

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

14 CHAIRMAN APOSTOLAKIS: Okay.

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

19 Here are some findings of the first
20 report.

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

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1 Engineering Education Research, NEER.

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

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

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

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

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

24 Another the system-on-chip circuitry and
25 this design approach, most of circuitry required for

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1 a system can be contained on a single IC.

2 MEMS, the microelectromechanical systems.

3 They have a combination of electrical mechanical
4 features in a very small package. And others.

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

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

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

20 MS. ANTONESCU: I wasn't here.

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

23 MR. KEMPER: Tritronics.

24 Bill Kemper.

25 MS. ANTONESCU: One of the ASICs

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1 experimentation of digital subsystem is the 7300 ASIC
2 based system by Westinghouse, which was developed in
3 1990s. And it is designed as an ASIC based
4 replacement model for the --

5 CHAIRMAN APOSTOLAKIS: So it is an
6 application-specific?

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

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

11 MS. ANTONESCU: They are PLC based.

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

14 MR. KEMPER: Yes. This is Bill Kemper.

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

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

21 MR. KEMPER: What we saw yesterday was a
22 microprocessor running application software. These
23 technologies are different in that it's a sea of
24 gates, and-gates and or-gates. And the programmer
25 uses technology to program those gates into solid

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1 state components, if you will. And the purpose and
2 the goal is to eliminate application software and
3 things like that. Therefore, it's a simpler
4 application, less complex, less subject to failures.

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

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

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

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

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

25 MR. GUARRO: Just a comment on the field

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

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

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

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

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

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

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

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

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1 will--

2 MR. ARNDT: We'll follow-up.

3 MR. KORSAH: Okay. This is Kofi Korsah.

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

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

15 MR. NGUYEN: And this is Thuy again.

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

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

25 MR. ARNDT: We actually have to programs

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

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

6 CHAIRMAN APOSTOLAKIS: Yes.

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

11 CHAIRMAN APOSTOLAKIS: And when will these
12 projects produce?

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

15 CHAIRMAN APOSTOLAKIS: All right.

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

19 CHAIRMAN APOSTOLAKIS: That's
20 International?

21 MR. ARNDT: That's international.

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

25 MR. ARNDT: Okay.

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

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

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

10 MR. KEMPER: This is Bill Kemper again.

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

14 CHAIRMAN APOSTOLAKIS: Their experience.

15 MR. KEMPER: Their experience? Okay.

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

18 MR. KEMPER: Broader.

19 CHAIRMAN APOSTOLAKIS: Is Brookhaven
20 looking at the broader experience?

21 MR. ARNDT: Yes.

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

25 MR. WATERMAN: This is Mike Waterman,

1 Research.

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

9 CHAIRMAN APOSTOLAKIS: Yes, that's --

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

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

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

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

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

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

25 MR. KORSAH: Can I interject here? Yes,

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

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

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

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

18 MR. ARNDT: Yes, it is. And what we're
19 talking about here is the ability to make real time
20 and near-real time application to do prognostics in a
21 plant and have both -- there's two sides of that. The
22 technology side of the actual thing you're trying to
23 deal with, tube integrity or pump vibration or
24 anything else. There's also the products issues
25 associated with it; how do you get that defined, how

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1 do you deal with that? A little more interesting the
2 latter than the former. But those issues,
3 particularly as you're dealing with longer and longer
4 cycle times and look more and more on issues
5 associated with the reliability of the system over the
6 cycle time it becomes more of an issue.

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

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

23 MR. GUARRO: Well, a comment on what was
24 said a moment ago about fault trace. I remember that
25 there was work done many years ago in using a fault

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1 trace line as a diagnostic tool, actually. When you
2 associate the model with real time sensor input, that
3 would be a way of identifying root cause for a set of
4 symptoms. Is there a revival of that type of thing?
5 Because this, there was something called disturbance
6 analysis, which was in 1980 or so.

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

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

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

24 CHAIRMAN APOSTOLAKIS: And why stability?
25 Micro assist ability, reliability. I understand the

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1 accuracy of the reliability. But the stability, what
2 does that mean?

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

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

14 MEMBER SIEBER: Well, stability has a
15 different --

16 MR. KORSAH: In a control sense, yes.

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

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1 CHAIRMAN APOSTOLAKIS: And ultimately it
2 becomes unreliable?

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

8 CHAIRMAN APOSTOLAKIS: Okay. Let's go on.

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

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

22 I mean, does this include understanding
23 modern theories for decision making, not necessarily
24 I&C oriented? And when you say role of human in
25 nuclear plant operations, you're going to probably

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1 have some psychologist telling you that they're going
2 to get bored and they're going to make mistakes. And
3 I don't know how much that helps you.

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

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

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

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

21 MR. ARNDT: Oh, yes.

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

25 MR. KORSAH: Well, this Kofi again.

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

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

10 CHAIRMAN APOSTOLAKIS: They are what?

11 MEMBER SIEBER: Are not taught to
12 operators.

13 MR. KORSAH: Yes, I know.

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

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

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

23 MR. ARNDT: Right. We just review that,
24 look at issues not only associated with the division,
25 but also the issues associated with if the licensee

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1 is making -- complaining that such-and-so can be done
2 by a human operator. For example, if the procedure is
3 going to be going forward and have a particular
4 mitigating action, the mitigating action as the
5 operator identifies the transient and makes the
6 action; those issues are something that we currently
7 have no position on. This research is looking at
8 those issues, but it's also looking at things
9 associated with how do you evaluate the design
10 decisions that they made associated with all the
11 control algorithms and level of complexity of those
12 issues.

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

17 MEMBER KRESS: I suspect that this --

18 MR. ARNDT: Yes.

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

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

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

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

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

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

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

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

18 MR. KEMPER: This is Bill Kemper.

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

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

3 MR. WATERMAN: This is Mike Waterman,
4 Research.

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

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

19 So those are a couple of examples where
20 you go to automated or you back away from automated,
21 depending upon what the circumstances. And this is
22 just an extension of that moving into other things
23 such as in a B&W plant when you have an accident, one
24 of the operator actions right now is to trip the
25 reactor coolant pumps when subcooling is lost. That's

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1 an operator action right now. Should it be automatic
2 where you just tie your subcooling margin monitor into
3 your system and trip RCPs. Don't know, you know. So
4 we need this kind of guidance to help us determine
5 whether or not that's a safe thing for the operator to
6 do or for the licensee to do.

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

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

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1 automation.

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

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

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

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

22 CHAIRMAN APOSTOLAKIS: Speak also to the
23 microphone, guys.

24 Okay, Christina.

25 MS. ANTONESCU: Then the area of high-

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1 integrity software. The survey findings confirmed the
2 need for near-term attention in two areas, as
3 identified in the Research Plan: Investigate
4 objective software engineering criteria and
5 investigate criteria for software testing. These two
6 areas are relevant because with no consensus regarding
7 necessary high-integrity software development and
8 testing practices and current processes do not give
9 comprehensive quantitative measures of quality and
10 fidelity.

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

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

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

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

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

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

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

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

25 MEMBER SIEBER: Before you flip off that

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1 slide, what is Johnson noise?

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

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

6 MR. KORSAH: Right. Yes.

7 MEMBER SIEBER: And remain ignorant.

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

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

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

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

10 MEMBER SIEBER: Now those detectors
11 deplete, right?

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

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

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

19 MEMBER SIEBER: Right.

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

25 MEMBER SIEBER: It depends on the geometry

1 of it, though? The thickness of the layers as to how
2 much it depletes.

3 MR. KORSAH: Right.

4 MEMBER SIEBER: And how sensitive it is.

5 MR. KORSAH: That is true.

6 MEMBER SIEBER: And it's over all
7 stability?

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

13 MEMBER SIEBER: Right.

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

19 MEMBER SIEBER: Right.

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

25 MEMBER SIEBER: Is there anything I could

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1 read that would give me information so I could learn
2 a little bit?

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

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

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

11 MEMBER SIEBER: It's better?

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

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1 MEMBER SIEBER: Okay.

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

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

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

19 MR. KORSAH: Right.

20 MEMBER SIEBER: And if you adjust that
21 output to equal what a measure would tell you power is
22 --

23 MR. KORSAH: Exactly.

24 MEMBER SIEBER: And then there's some
25 error there which you compensate for in your

1 regulatory structure. Would this be more accurate or
2 less accurate?

3 MR. KORSAH: It would be more accurate.

4 MEMBER SIEBER: Okay.

5 MR. KORSAH: Okay.

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

8 MR. KORSAH: Exactly.

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

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

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

15 MR. KORSAH: That's what we think.

16 MEMBER SIEBER: Yes.

17 MR. WATERMAN: Mike Waterman, Research.
18 This looks interesting. How long is your
19 sensor?

20 MR. KORSAH: How long?

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

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

24 MR. WATERMAN: So you'd need then spaced
25 vertically over several different locations in the

1 corridor to account for the fact of your flux?

2 MR. KORSAH: To get it through there.

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

7 MR. KORSAH: Right.

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

10 MR. KEMPER: This is Bill Kemper.

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

15 MR. KORSAH: Right.

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

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

21 MR. KEMPER: Exactly. Right.

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

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

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

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

13 MEMBER SIEBER: Right.

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

17 MEMBER SIEBER: Right.

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

22 MEMBER SIEBER: Right.

23 MR. KORSAH: The bandwidth can be set as
24 constant is constant, right? So everything then is
25 just basically put on temperature. Everything is a

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1 constant. And then the neat thing about it, because
2 it means, you know, just this hot, and we know that,
3 you know, at current temperature measurement and
4 measurement devices, if you can have the temperature
5 measurement device that is free of drift, you know,
6 that calibration into the example, you know, can be --
7 you know can be revealed.

8 MEMBER SIEBER: So this acts like an RTD?

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

13 MEMBER SIEBER: Right.

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

21 MEMBER SIEBER: Right.

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

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1 is more accurate, right?

2 MEMBER SIEBER: Calibrated --

3 MR. KORSAH: To calibrate the RTD exactly.

4 Roger is in fact one of the experts --

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

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

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

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1 that measurement becomes.

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

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

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

20 Does that help you in your --

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

24 MR. KISNER: There are other kinds of
25 noise other than Johnson noise. There's a shock

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1 noise. There's one over F noise. There's, you know,
2 various kinds of noise that occur. And they have to
3 do more with how those bound, the structure of the
4 material, phonon vibrations and effects of the
5 material.

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

13 MEMBER SIEBER: And they're not bound.

14 MR. KISNER: And they're not bound.

15 MEMBER SIEBER: Okay. Thank you.

16 MR. KISNER: You're welcome.

17 MR. KORSAH: One of the areas that at
18 least I heard Steve talk about was rad-hardened
19 electronics. We looked at what is coming down the
20 pike in terms of rad-hardened electronics. It's very
21 likely to come into the pipeline environment very
22 soon. And we found out that there are rad-hard
23 electronics to the systems right now that are
24 becoming, you know, better and better, okay? One is
25 silicon-insulator, okay. And one is chalcogenide

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1 where they're using the chalcogenide material with
2 red-hardened CMOS process to make a system that we
3 have now.

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

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

25 MEMBER SIEBER: And it certainly

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1 simplifies calibration.

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

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

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

11 MEMBER SIEBER: Yes.

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

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

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

19 MEMBER SIEBER: Yes.

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

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

1 MR. KORSAH: Right. Right.

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

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

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

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

25 CHAIRMAN APOSTOLAKIS: Can we speed it up

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1 a little bit?

2 MR. KORSAH: Yes, I hope so.

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

5 MEMBER SIEBER: I'll try to control
6 myself.

7 CHAIRMAN APOSTOLAKIS: Okay.

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

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

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

19 MS. ANTONESCU: Right.

20 CHAIRMAN APOSTOLAKIS: Okay.

21 MEMBER SIEBER: Ah, cell phones.

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

24 MS. ANTONESCU: All right. So my name is
25 Christina Antonescu. I'm here to discuss

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1 confirmatory research that we are presenting
2 conducting on implementation of wireless technology.

3 This topic can be found in the Section
4 2.5.6 in the Digitalized Plan covering 2005 through
5 2009.

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

12 This project is ongoing. It began in
13 2001. And it is scheduled to be completed in FY 2007.

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

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

25 MS. ANTONESCU: All right.

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

3 MS. ANTONESCU: Right.

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

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

9 MS. ANTONESCU: To. All right.

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

12 MEMBER SIEBER: Some members, yes.

13 CHAIRMAN APOSTOLAKIS: Christina --

14 MS. ANTONESCU: Yes, sir.

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

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

20 MR. KEMPER: This is Bill Kemper.

21 Before we leave that last slide, if you
22 could go back, Paul. We have a glitch. At any rate,
23 the point I was trying to make is on that previous
24 slide it says wireless systems have potential to cause
25 safety problems and it mentions cybersecurity

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1 breaches. You recall yesterday morning we talked
2 about this in the cyber area. I want to be sure that
3 we don't confuse you all.

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

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

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

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

24 The phase one assessment of the state of
25 wireless systems identified distinctive wireless

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1 technology features that could be used to distinguish
2 between different wireless products, which I'm going
3 to cover later on.

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

6 MS. ANTONESCU: Yes.

7 MEMBER KRESS: Not infrared or -- okay.

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

10 MEMBER KRESS: Okay.

11 DR. EWING: It could be.

12 MEMBER KRESS: Could be?

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

15 MEMBER KRESS: All right.

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

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

25 CHAIRMAN APOSTOLAKIS: What does

1 unlicensed versus licensed mean?

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

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

10 CHAIRMAN APOSTOLAKIS: I see.

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

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

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

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

23 DR. EWING: Yes, that is true.

24 MEMBER SIEBER: If you're licensed,
25 though, you have to build it by hand. So you've got

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1 to be a little smarter cookie to do that than just
2 going down to the local store and buying something.

3 CHAIRMAN APOSTOLAKIS: Okay.

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

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

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

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

16 And the type of modulations employed.

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

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

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1 proceed.

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

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

8 CHAIRMAN APOSTOLAKIS: But what does that
9 mean?

10 MS. ANTONESCU: Okay. Well --

11 CHAIRMAN APOSTOLAKIS: Explain the star
12 network, for example.

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

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

25 MS. ANTONESCU: These are different

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

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

5 DR. EWING: Each sphere represents --

6 CHAIRMAN APOSTOLAKIS: What's a sphere?

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

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

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

15 CHAIRMAN APOSTOLAKIS: So are these --

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

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

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

23 CHAIRMAN APOSTOLAKIS: Okay.

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

25 CHAIRMAN APOSTOLAKIS: So if two spheres

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

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

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

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

8 DR. EWING: Communication. Sorry.

9 MR. KEMPER: This is Bill Kemper.

10 CHAIRMAN APOSTOLAKIS: The questions
11 sometimes are very simplistic.

12 MS. ANTONESCU: Okay.

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

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

24 It should be noted that the standards
25 have been developed that specify how each type of

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1 network will operate. And along with its specific
2 area of coverage, each type of network has designated
3 beta throughput rate and bandwidth operation. And
4 we're going to discuss some of these familiar types of
5 networks in the market today, which include Wifi and
6 Bluetooth, WIMAX.

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

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

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

23 So if you look at the table which
24 summarizes some of these features that we mentioned
25 before, you can see on the first column shows the

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1 different available standards. 802.15 which is
2 Bluetooth and ZigBee, then WiMAX you got 2.16b. And
3 the Wifi to different versions.

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

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

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

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

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

25 So the deployment issues include the

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

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

9 Next page, our investigation also showed
10 that EMI interference effects could possibly impact
11 the digital I&C safety functions linked to wireless
12 devices. And the occurrence of interference between
13 802.11, which is Wifi devices and the Bluetooth, the
14 802.15 have been documented. And 24 of 79 channels
15 were found to be susceptible to interference from the
16 802.11b, which is are the Wifi networks. That is that
17 the 24 of the 79 channels available for Bluetooth did
18 not work. And the Bluetooth interference to 802.11g
19 networks also was found to be similar.

20 So redundancy is one means of addressing
21 some potential interference.

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

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

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

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

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

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1 EMI guidance should be followed.

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

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

10 MS. ANTONESCU: No.

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

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

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

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

22 MEMBER SIEBER: If you wanted to mess up
23 a control system using wireless in a nuclear power
24 plant, you don't need to know anything about the
25 protocol or encryption or anything. All you need is

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1 a stronger signal to wipe it out.

2 MEMBER KRESS: That's what I was thinking.

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

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

8 MEMBER SIEBER: You might have --

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

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

12 MEMBER SIEBER: Yes.

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

15 DR. EWING: No, it doesn't.

16 CHAIRMAN APOSTOLAKIS: Okay, Christina.

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

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1 lab, probably.

2 So the results of the project are
3 progressing as planned and we do have a NUREG/CR which
4 was completed in July 2005, and it's called Assessment
5 of Wireless Technologies and Their Application at
6 Nuclear Power Plants. And the phase two effort is
7 proceeding on course. We're looking on a second
8 NUREG/CR entitled Assessment of Industrial Wireless
9 Protocols. This first draft was completed in March,
10 2005 and it reports on the modeling and simulation
11 progress to that point. It will be updated in March of
12 2006 to report on the conclusion from phase two.

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

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

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

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1 someone has questions.

2 CHAIRMAN APOSTOLAKIS: Any questions?

3 Thank you very much. Appreciate it.

4 We will recess until 10:30.

5 (Whereupon, at 10:09 a.m. a recess until
6 10:36 p.m.)

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

10 MR. ARNDT: That's correct.

11 CHAIRMAN APOSTOLAKIS: Well, Mr. Arndt.

12 MR. ARNDT: Thank you, Professor
13 Apostolakis.

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

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

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

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

17 The first major document on that was a
18 work that we published in 1995 "On-Line Testing of
19 Calibration of Process Instrumentation Channels in
20 Nuclear Power Plants." And basically it was to look
21 at the technology, to review the technology, to
22 understand the technology and determine whether or not
23 this was something that we should really keep an eye
24 on because it was or was not going to be feasible in
25 nuclear power plants. And the conclusions of that was

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1 that there are a lot of opportunities in this area and
2 it is feasible.

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

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

17 In the last few years EPRI and a number of
18 plants have looked at this both for diagnostic issues,
19 the issue of understanding how the systems are working
20 looking at both the safety and nonsafety systems from
21 a diagnostic/prognostic kind of area as well as a
22 specific application that we're talking about for
23 sensitive calibration. As you've heard, there's been
24 a lot of research associated with putting new digital
25 systems in the plant, so there's several different

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1 applications of this. One is the specific tech spec
2 type issues, but there's also other areas that we're
3 going to get to after we finish looking at this.

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

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

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

25 One of the big issues is the training

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

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

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

23 So we organized the project basically in
24 three phases. The first phase is basically to update
25 the state-of-the-art. Where are we today as opposed

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1 to what we've looked at in the past? What are the
2 issues? What are the technical challenges associated
3 with it? How does that related to the 14 points that
4 were required in the SER?

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

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

20 So, for example, we'll use some plant data
21 and come up -- well, if they're right on the bad edge
22 of this particular side of the box or that side of the
23 box, what kind of information are you going to see.
24 So we're going to have a state-of-the-art information
25 on how the system works, we're going to have a tool to

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1 allow the reviewer if he wants to do so some
2 independent audit calculations, and we're going to
3 have a reference document to say these are the outputs
4 that you might want to have a concern about.

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

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

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

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

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

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

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

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

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

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

23 So the technique, the empirical modeling
24 techniques that we've examined are the empirical
25 modeling techniques that are being used out there

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1 right now and experimented with and pilot studied at
2 nuclear power plants.

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

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

22 The other techniques are Monte Carlo based
23 techniques. Basically you sample and you build a
24 couple of thousand models and you look at how do the
25 outputs vary. And that, again, will give you the

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1 uncertainty portion or the variance portion of the
2 uncertainty.

3 So two different techniques.

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

6 CHAIRMAN APOSTOLAKIS: Excuse me.

7 MR. HINES: Yes, sir?

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

15 MR. HINES: No.

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

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

22 CHAIRMAN APOSTOLAKIS: Yes. I know that.
23 Yes.

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

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1 CHAIRMAN APOSTOLAKIS: I know, but --

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

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

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

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

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1 CHAIRMAN APOSTOLAKIS: Yes.

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

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

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

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

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

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

22 CHAIRMAN APOSTOLAKIS: Yes.

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

25 CHAIRMAN APOSTOLAKIS: Yes. But you said

1 the square root of the variance.

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

4 CHAIRMAN APOSTOLAKIS: But you don't --

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

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

11 MR. HINES: Right. And then you --

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

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

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

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

22 Okay. So you have to calculate these two
23 things separately. The past people like Argonne who
24 did some of the early uncertainty analysis for MSET,
25 they only did the Monte Carlo technique and they were

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1 looking at the variance. So they were basically saying
2 that they were unbiased models. And it's a pretty
3 good assumption when you're in the middle of certain
4 operating conditions. But you need to take both of
5 those into consideration.

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

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

18 But these techniques have been developed
19 or in the statistical literature. We've applied them
20 to nuclear power plant data. We've bootstrapping
21 techniques to validate that, yes, they do give you the
22 correct results. So you can either have analytical
23 techniques running on-line with your model, or what's
24 more prevalent in industry right now is that they
25 would use Monte Carlo techniques and they would take

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1 average values for models, and say here's my
2 uncertainty of this model.

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

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

17 So Monte Carlo technique basically you
18 sample from the data, you develop a model. You sample
19 again, you develop another model. You develop a 1,000
20 models and you look at the variance between the
21 models. So you're getting a true estimate of what do
22 you think. You know, how repeatable are your modeling
23 results. And with these techniques, that's extremely
24 important because the data that goes into these models
25 are highly collinear, highly correlated. And when you

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1 model with correlated data you get what's called an
2 ill-posed problem. You can get huge variances. And
3 one model looks good, but you need to do it over and
4 over to make sure that you get consistent, reliable,
5 repeatable results.

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

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

22 But you de-noise it to get distributions
23 of the noise that's on your data and then you use the
24 de-noise data and you sample from that, and then you
25 sample from your noise distribution and you build your

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1 model. Then you do that over and over. And because
2 you have the noise distribution, you can sample at a
3 more intelligent manner and that's where you get into
4 the Latin Hypercube Sampling and have fewer iterations
5 to give the same reliability to your uncertainty
6 predictions. So it's a much more complicated
7 technique.

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

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

24 MR. HINES: Okay.

25 CHAIRMAN APOSTOLAKIS: The whole idea of

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

3 MR. HINES: Right.

4 CHAIRMAN APOSTOLAKIS: With some
5 uncertainty.

6 MR. HINES: Yes.

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

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

15 CHAIRMAN APOSTOLAKIS: Right.

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

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

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

9 CHAIRMAN APOSTOLAKIS: You're out.

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

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

25 MR. HINES: Now we're actually using data

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

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

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

15 MEMBER KRESS: Yes.

16 MR. HINES: That was done by Argonne.

17 MEMBER KRESS: Okay.

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

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

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

25 MEMBER KRESS: Yes.

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

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

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

25 This slide is the on the process equipment

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1 monitoring toolbox. This is the user manual that goes
2 along with it. It says the user manual, the tutorial
3 and the guide and then a little description and
4 example usages of it.

5 CHAIRMAN APOSTOLAKIS: Is that that NUREG
6 or--

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

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

18 And then for a third NUREG we're going to
19 go in and look at limiting case studies. If these
20 assumptions aren't completely met, how do they effect
21 the results? And if you start getting outside of your
22 operating condition, does this thing fail? The way it
23 should fail is your uncertainty should just blow up
24 because you no longer have confidence on your model
25 predictions. And does that do that or do you need an

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1 additional module that says are we now operating
2 within the limits of our training data? So we're
3 looking at all these limiting case studies for the
4 third NUREG.

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

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

13 MR. ARNDT: Probably.

14 MEMBER SIEBER: Yes.

15 MR. ARNDT: Yes.

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

18 MR. ARNDT: Yes.

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

21 MR. HINES: This? Yes, sure.

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

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

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

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

11 CHAIRMAN APOSTOLAKIS: Who is this fellow
12 you mentioned twice?

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

21 CHAIRMAN APOSTOLAKIS: So where is he now?

22 MR. HINES: Sun Microsystems hired him.
23 You know, if we have a trip in a reactor it costs you
24 a million dollars, you know, you lost day. If they
25 lose an hour of eBay, that might be \$8 million. So

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1 they keep going up to the more expensive type of
2 processes.

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

5 MR. HINES: Yes, sir.

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

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

22 And so there are a lot of rules like that.
23 So if you look at the second to the bottom it says
24 "expected correlation." This would be the correlation
25 of the noise that you removed. Actually, it basically

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1 has a correlation of zero, wavelet finds that out.
2 ICA removes a little bit too much noise.

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

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

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

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

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

3 MR. HINES: Okay.

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

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

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

10 MR. HINES: Yes.

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

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

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

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

22 MR. HINES: The vendors are really -- and
23 I think this one reason V.C. Summer hasn't stepped up
24 the plate yet. The vendors don't have -- this has
25 been done more in the research field rather than the

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1 vendors actually applying this and incorporating it
2 into their products. And I think that's why V.C.
3 Summer is slow to put in this license amendment
4 because they're using Expert Microsystem's product and
5 Expert Microsystem has not finalized the version where
6 they've incorporated these uncertainty analysis
7 modules.

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

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

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

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1 data. So that's why it's being studied.

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

7 CHAIRMAN APOSTOLAKIS: So you had already
8 developed ICA?

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

11 CHAIRMAN APOSTOLAKIS: Oh, I'm sorry.

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

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

17 MR. HINES: Yes, sir.

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

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

22 CHAIRMAN APOSTOLAKIS: Right.

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

25 CHAIRMAN APOSTOLAKIS: Oh, he applied the

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1 ICA? He didn't develop it?

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

4 CHAIRMAN APOSTOLAKIS: Oh.

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

7 CHAIRMAN APOSTOLAKIS: Okay.

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

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

20 Then the prediction, the autoassociative
21 kernel regression is what Smart Signal uses.
22 Autoassociative MSET is what Sure Sense used.
23 Autoassociative MSET is the company in Chicago. And
24 autoassociative neural networks in the Holland Reactor
25 Project. So the three models were chosen because

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1 that's the three things that have been used in the
2 EPRI implementation plan, was the three techniques
3 that have been used out there. So the ones we really
4 need to know about.

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

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

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

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

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

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1 techniques are being applied.

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

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

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

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

25 MR. WATERMAN: Yes.

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

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

9 MR. HINES: Right.

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

13 MR. HINES: Right.

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

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

20 MR. WATERMAN: Okay.

21 MR. HINES: The whole project is to give
22 the regulators to the tools. The first NUREG says
23 where do you go to find this information. There's ten
24 years of literature out there. You know, you have 14
25 requirements. What literature corresponds to what

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1 requirements and where do you go and how do you learn
2 these things. So that's kind of a quick reference
3 manual.

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

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

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

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

18 MR. WATERMAN: This is Mike Waterman
19 again.

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

24 CHAIRMAN APOSTOLAKIS: No. No. I
25 understand that.

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

10 CHAIRMAN APOSTOLAKIS: And you do that via
11 regulatory guides?

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

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

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

20 CHAIRMAN APOSTOLAKIS: Yes, I understand.

21 MR. ARNDT: And it's very much case
22 specific. In this case it's a fairly narrow kind of
23 application so it probably wouldn't be a reg guide.
24 In this case one way to do it would be to go back to
25 the original generic SER and the 14 points that are

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1 necessary to be acceptable for a case specific
2 application. And appropriate application of
3 uncertainty estimation is one of the things that is
4 required.

5 CHAIRMAN APOSTOLAKIS: Yes.

6 MR. ARNDT: So that could be the link.

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

13 MR. ARNDT: Yes.

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

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

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

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

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

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

9 MR. HINES: Yes.

10 CHAIRMAN APOSTOLAKIS: Because you are an
11 academic.

12 MR. ARNDT: Let's go for it.

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

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

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

8 Another method that's been used by Argonne
9 Labs called the SPRT, the sequential probability ratio
10 test, rather than kind of doing an average, this is a
11 technique that determines where the greater
12 probability is that this residual train has come from.
13 This distribution that has a mean of zero, meaning the
14 residual hasn't drifted or this other distribution
15 that has a mean of let's say, 1 percent saying that it
16 has drifted. So it's a statistical technique that
17 determines from incoming train of residuals what the
18 probability is that it comes from an unfaulted mean
19 distribution or a distribution that has some faulted
20 mean. And this is an example of our residual growing
21 with time and then a fault hypothesis. It's a
22 powerful technique that was developed by Wald back in
23 1947.

24 Okay. So conclusions. We've turned in
25 one NUREG. The second NUREG's been turned in in a

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1 draft form. The toolbox will be turned probably in
2 December.

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

5 MR. HINES: A year.

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

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

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

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

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

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

20 MEMBER SIEBER: And they won the football
21 game?

22 CHAIRMAN APOSTOLAKIS: What?

23 MEMBER SIEBER: They won the football
24 game, too.

25 CHAIRMAN APOSTOLAKIS: Wonderful.

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

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

8 Derivation and application of analytical
9 uncertainty estimation techniques.

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

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

17 Also in this second part where we're doing
18 the limited case studies, we're not only using or
19 toolbox, but we have compiled a code for the models
20 from both Smart Signal and from Expert Microsystems.
21 So we're going to compare what their compiled --
22 because they don't want to give you the actual source
23 codes. I don't want it anyway because it has IP, it's
24 important to them to keep that secret. But they've
25 told us what the algorithm uses and we can compare

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1 that with our implementation of the algorithm and
2 compare and see do their tools give you the results
3 that we would expect? And so far the early results
4 there is they give us exactly the same. You know,
5 there's a little bit of random uncertainty, you know,
6 as always then they use Monte Carlo techniques. But
7 they perform exactly as expected.

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

11 CHAIRMAN APOSTOLAKIS: Right.

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

15 CHAIRMAN APOSTOLAKIS: Thanks.

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

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

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

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

25 MR. WATERMAN: Yes.

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

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

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

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

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

23 MR. WATERMAN: And I was sort of looking
24 at this as a similar type of application where the
25 licensee comes in and says this is the model we used,

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1 and here's the data and this is the result and
2 therefore you can license it. And we take the toolbox
3 and we say we're going to do an independent analysis.

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

6 MR. WATERMAN: Okay.

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

10 MR. WATERMAN: Okay.

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

13 CHAIRMAN APOSTOLAKIS: That's it?

14 MR. ARNDT: That's it.

15 CHAIRMAN APOSTOLAKIS: Thank you very much.
16 Thank you.

17 MR. HINES: Thank you.

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

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

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1 will request a letter?

2 MR. KEMPER: Yes.

3 CHAIRMAN APOSTOLAKIS: Saying what?

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

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

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

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

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

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

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

5 MR. KEMPER: We've been through this once
6 before. We can pull the memo what happened with the
7 previous search plan that you all approved back in
8 2000.

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

16 MR. KEMPER: Right.

17 MR. ARNDT: We're check.

18 CHAIRMAN APOSTOLAKIS: Sorry.

19 MEMBER SIEBER: We could write a letter
20 to--

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

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

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

3 MEMBER SIEBER: Even without a
4 recommendation.

5 CHAIRMAN APOSTOLAKIS: And leave it at
6 that?

7 MEMBER SIEBER: Yes.

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

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

12 MR. KEMPER: Yes.

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

15 MEMBER BONACA: One comment had, yes, and
16 I would like to repeat. I mean, to me I think it is
17 a good plan. I am very appreciative of the plan
18 because I think it gives also a coherent summary of
19 all that you're planning to do. There is information
20 that you do have about the challenges, examples of the
21 challenges, I mean in the field. To the degree to
22 which you can provide them, it gives further imports
23 to the need for the work. In some cases, it really
24 makes it -- you know, you get an understanding of how
25 this new technology that is being implements all over

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1 the place, it's representing a challenge right now.
2 I think that would be useful to the Committee.

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

5 CHAIRMAN APOSTOLAKIS: An hour and a half.

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

9 CHAIRMAN APOSTOLAKIS: That's right.

10 MEMBER KRESS: And I don't --

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

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

16 MEMBER KRESS: Yes.

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

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

23 CHAIRMAN APOSTOLAKIS: Yes.

24 MEMBER KRESS: Get down to that level.

25 CHAIRMAN APOSTOLAKIS: How does it meet --

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

3 MEMBER KRESS: Right.

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

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

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

13 CHAIRMAN APOSTOLAKIS: I would start with
14 the replacements.

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

17 MEMBER KRESS: Right.

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

25 CHAIRMAN APOSTOLAKIS: Exactly. Exactly.

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

4 CHAIRMAN APOSTOLAKIS: Yes. Yes.

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

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

11 MR. ARNDT: Yes.

12 MR. KEMPER: Yes. Five, actually.

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

25 Now, as Jack said, you know you start by

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1 setting in context and so on. But don't forget the
2 fundamental question. We are doing something, we are
3 expending resources to meet Agency's need.

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

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

10 MEMBER KRESS: Somebody with the EMI and--

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

15 MEMBER KRESS: Just cannot get that
16 detailed.

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

23 MEMBER BONACA: That was my comment, by
24 the way, that Jack actually verbalized much better.
25 The need for context, however, is important. Because

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1 this is my opinion. I've attended a number of these
2 presentations and they have been all high level. Too
3 many statements about we will do this and this, which
4 presume a level of understanding of the issues in the
5 field, the problems, the challenges there are. I
6 think part of the Committee would be lost in that very
7 high level.

8 MEMBER SIEBER: I think so, too.

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

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

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

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

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

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

5 MR. ARNDT: Right.

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

13 MR. ARNDT: Okay.

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

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

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

23 MR. ARNDT: Yes. I think we can probably
24 work some of that into maybe a thread example
25 throughout the issue based on one of the current

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1 applications or something like that.

2 MEMBER SIEBER: Right.

3 MR. ARNDT: Or data, computational
4 results.

5 MEMBER SIEBER: Ocone would be an
6 example.

7 MR. ARNDT: Ocone or --

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

10 MR. ARNDT: Okay.

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

13 MR. ARNDT: Okay.

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

16 MR. ARNDT: Yes.

17 CHAIRMAN APOSTOLAKIS: You think so?

18 MEMBER KRESS: I would think so.

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

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

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

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

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1 MR. ARNDT: Oh, yes.

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

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

13 MEMBER BONACA: Yes. The fact is, you
14 know, as you all recall back in May we presented or we
15 tried to present the entire plan in a fair amount of
16 detail. So much so we didn't get through the
17 presentation. But any rate, that information wasn't
18 made available to the Committee. So I'm hoping that
19 we can bank on some of that memory still being there,
20 if you will, or familiarity still being there with the
21 plan. I mean, we could just redo that, but I don't
22 know --I'm hoping that from this time since we've had
23 this interaction with you all, we can go to a higher
24 level, though. Albeit I respect what you're saying,
25 you know, but if we get mired down too much and we

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1 talk about wavelet de-noising, you know what happens
2 there. We'll end up getting all tangled up and we'll
3 never get through.

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

7 MR. ARNDT: Yes.

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

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

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

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

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

21 MEMBER SIEBER: And he will.

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

25 MEMBER SIEBER: And he will.

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1 CHAIRMAN APOSTOLAKIS: Huh?

2 MEMBER SIEBER: And he will.

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

6 CHAIRMAN APOSTOLAKIS: It's up to you.

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

11 CHAIRMAN APOSTOLAKIS: Figures area always
12 preferable.

13 MR. ARNDT: Yes.

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

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

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

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

25 CHAIRMAN APOSTOLAKIS: And you will have

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1 already justified the --

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

4 CHAIRMAN APOSTOLAKIS: The current event
5 will have been justified.

6 MR. ARNDT: Why we have these particular--

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

10 MR. ARNDT: Right.

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

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

23 MR. ARNDT: Yes.

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

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

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

7 MEMBER KRESS: I think so.

8 MEMBER SIEBER: I'm exhausted.

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

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

14 MR. GUARRO: Yes.

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

17 MEMBER BONACA: I already expressed the
18 opinion.

19 CHAIRMAN APOSTOLAKIS: Which is?

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

23 CHAIRMAN APOSTOLAKIS: No.

24 MEMBER BONACA: I mean, that's not the
25 point. The point is that I think it's a comprehensive

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1 view of what the situation is and the challenges that
2 I think NRR is going to face in the future. I think
3 there is sufficient consideration of users need, and
4 that's an important element that we always question.

5 CHAIRMAN APOSTOLAKIS: Very good.

6 Sergio?

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

13 CHAIRMAN APOSTOLAKIS: Okay. Very good.

14 Tom?

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

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

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

21 MEMBER SIEBER: You aren't done asking
22 everyone.

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

25 CHAIRMAN APOSTOLAKIS: Except the

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

2 MEMBER KRESS: That's an automatic --

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

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

7 CHAIRMAN APOSTOLAKIS: Mr. Sieber?

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

22 And so the question is when we look in the
23 crystal ball, are we picking the right things to
24 direct our money at? And so if I were to question
25 anything at all, I would question are these the right

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1 tasks? And I'm not sure that we as ACRS can come up
2 with any better answer than the Staff can come up
3 with. But I think we need to somehow, at least
4 personally I have to look at and address that issue so
5 that I'm convinced that these are the right things to
6 do. And I think that we would write a really good
7 letter if we were all convinced and would say these
8 are the right things to do based on what we know
9 today. But otherwise, I actually do think they're the
10 right things to do. Yes, but on the other hand, I
11 don't have a basis yet

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

15 MEMBER SIEBER: Yes.

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

20 MEMBER SIEBER: Why these?

21 CHAIRMAN APOSTOLAKIS: --and not something
22 else.

23 MEMBER SIEBER: Yes.

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

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

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

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

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

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

22 MR. ARNDT: It is. That's right. And
23 it's both a prioritization between individual topics,
24 it's a prioritization between today needs versus
25 tomorrow needs. It's a prioritization on how much

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1 time you spend looking and how much you time spend
2 doing. So there's a dimensions to that, and we'll try
3 and address that as best we can.

4 MR. GUARRO: You also have a timetable for
5 implementation. I mean, you are planning for
6 2006/2007. So you have time to get to a closer
7 horizon and make decisions on whether you should just
8 drop something and do something else?

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

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

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

18 MR. ARNDT: Yes.

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

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

23 CHAIRMAN APOSTOLAKIS: Yes. And maybe
24 NMSS, too.

25 MR. ARNDT: Yes.

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

3 MR. ARNDT: Well and NCR.

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

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

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

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

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

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

20 CHAIRMAN APOSTOLAKIS: So the letter
21 should address everything then.

22 MEMBER SIEBER: Yes.

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

25 CHAIRMAN APOSTOLAKIS: Okay. So NSIR

1 should be here as well?

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

5 CHAIRMAN APOSTOLAKIS: Okay. Is there
6 anything else.

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

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

23 MR. KEMPER: And I'd like to just make a
24 statement before we close, too. As I said at the
25 outset of this meeting, I really appreciate you alls

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1 participation and the time that we've been able to
2 spend with you. I guess this is like the second day
3 and a half session here. So we've spent a lot of
4 time. But we really appreciate the valuable insights
5 that you give us. And I look forward to interacting
6 with you on many more of these projects in the future
7 over the next, who knows.

8 CHAIRMAN APOSTOLAKIS: Very good. Thank
9 you very.

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

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

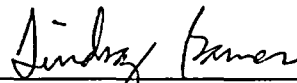
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Name of Proceeding: Advisory Committee on
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Digital Instrumentation and
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Emerging Digital Technology and Applications Overview (3.5)

**Advisory Committee on Reactor Safeguards
Digital Instrumentation and Control Subcommittee**

October 21, 2005

Steven Arndt

**Division of Engineering Technology
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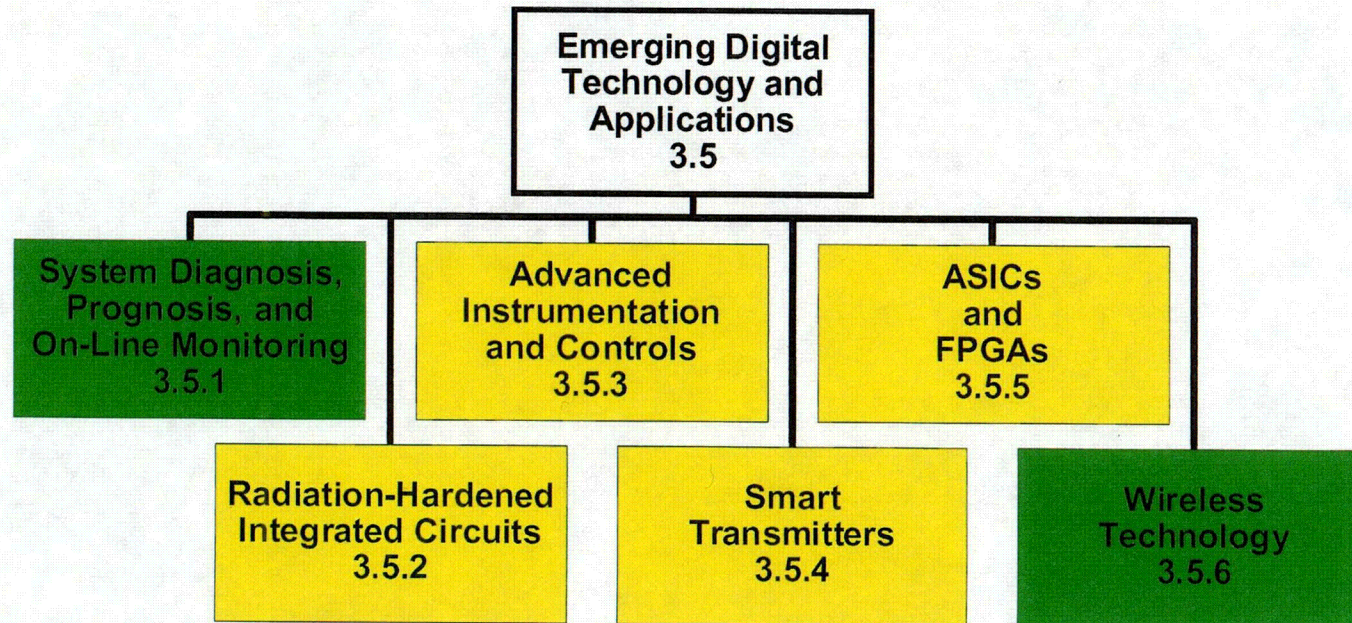
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Emerging Digital Technology and Applications Program



Emerging Technology and Applications Program

- Vendors, licensees, owners groups, and nuclear industry will continue to develop and propose new technologies for nuclear facilities
- Knowledge about these new, emerging technologies is critical for NMSS, NRR, and NSIR staff to license these technologies in safety related applications in an effective and realistic manner
- The research program in this area includes
 - Developing additional information
 - Developing assessment tools and review methodologies
 - Revising regulatory guidance to support unique features of each new technology

Emerging Technology and Applications Program

- This part of the research program will include an effort to identify important emerging technology, and investigating the technologies that may have a regulatory impact
- Ongoing projects include
 - Emerging technology evaluations
 - On-line Monitoring
 - Wireless technology
- Future project include
 - System Diagnosis and Prognosis
 - Advance Instrumentation
 - Advanced Controls
 - Radiation Hardened Integrated Circuits
 - ASIC's and FPGA's
 - Smart Transmitters

Emerging I&C Technologies Have a Potential Regulatory Impact

- **REQUEST:** User Need NRR-2002-017
- **ACTION:** Investigation of emerging technologies is included in the NRC Digital Research Plan for FY 2001- FY 2004
- **BENEFIT:** The NRC will be better prepared to make future regulatory decisions in these areas by becoming informed of emerging I&C technologies and applications postulated for use in nuclear power plants in a timely manner

RES Initiated an On-Going Study of Emerging I&C Technologies

- **Approach:**
 - Survey significant technological advances
 - Assess prospective applicability for NPPs
 - Identify potential research needs for consideration
 - Confirm elements of NRC Digital Research Plan
 - Contribute to updated I&C Research Plan
- **Reviews of the Emerging Technologies Are Presented as Periodic Reports**
 - Staff reviews, findings and evaluate need for focus research in specific areas.

I&C Technology Survey Findings Were Reported in NUREG/CR 6812

- **Technological Focus Areas:**
 - Sensors and measurement systems
 - Communications media and networking
 - Microprocessors and other integrated circuits
 - Computational platforms (computers, programmable logic controllers, application specific integrated circuits, etc.)
 - Diagnostics and prognostics
 - Control and decision
 - Human-system interactions
 - High-integrity software

Findings on the Focus Areas Are Summarized in the First Report

- **Sensors and Measurement Systems**
 - Several new radiation, power, and process sensors were under development as a result of the research stimulus provided by the DOE programs NERI, International NERI, and Nuclear Engineering Education Research (NEER)
 - Report recommended to follow their progress because of their potential for implementation in nuclear power plants, with attendant improvements in operating margins, etc.
- **Communications Media and Networking**
 - The survey anticipated the application of wireless technology to increase because of their cost, availability, and flexibility
 - The report recommended near-term research to better characterize the deployment issues

Findings on the Focus Areas Are Summarized in the First Report (cont'd)

- **Microprocessors and Other Integrated Circuits**
 - Survey identified key I&C technologies that merited long-term monitoring because of their significance for nuclear applications
 - Radiation-hardened ICs
 - Optical processors (in particular, optical digital signal processors)
 - Nanotriodes
 - System-on-chip (SoC) circuitry
 - Microelectromechanical systems (MEMS)

Findings on the Focus Areas Are Summarized in the First Report (cont'd)

- **Computational Platforms (computers, programmable logic controllers, ASICs, etc.)**
 - Application-Specific Integrated Circuits (ASICs) and real-time operating systems were identified as technologies to be monitored
 - Increased cost of dedicated commercial software-based systems pointed to increased applications of ASICs
 - Performance and reliability characteristics of operating systems must be well-understood

Findings on the Focus Areas Are Summarized in the First Report (cont'd)

- **Diagnostics and Prognostics**
 - Survey confirmed the need for continued monitoring of these technologies
 - Likely integration of control and diagnostics for autonomous plant operation
 - Expected greater reliance on surveillance and prognostic methods to facilitate predictive maintenance
 - Methods for assessing accuracy, stability, and reliability of diagnostics and prognostic techniques are appropriate candidates for near-term research

Findings on the Focus Areas Are Summarized in the First Report (cont'd)

- **Control and Decision**
 - Most significant change expected may be the transfer of more and more of the decision-making responsibility to I&C systems
 - Consideration should continue to be given to:
 - role of human in nuclear plant operations;
 - capabilities and reliability of autonomous control systems (familiarity with capabilities and configuration options of highly autonomous control systems should be developed before the long-term deployment concepts reach fruition)

Findings on the Focus Areas Are Summarized in the First Report (cont'd)

- **High-integrity Software**
 - Survey findings confirmed the need for near-term attention in two areas, as identified in the I&C Research Plan:
 - Investigate Objective Software Engineering Criteria
 - Investigate Criteria for Software Testing

Second Report Used the Same Focus Areas, but With Emphasis on the Sensor Technologies

- **Summary Updates For the Technology Focus Areas Are Provided**
- **Sensors and Measurement Systems Focus Area Was Selected For More Detailed Study:**
 - Sensors are likely to have the greatest safety impact because they have a direct bearing on operating and protection margins;
 - Some new sensor designs have the likelihood of maturing into commercial deployment in power plants in the near term;
 - Some of the most significant advances in the technology focus areas are in the area of sensors.
- **Potential Regulatory Impact of Each of the Sensor Technologies Is Discussed**

Updates on Technology Focus Areas are Provided in Second Report

- **Sensors and Measurement Systems**

- New sensors are being developed that are close to commercialization (e.g., silicon carbide detector, fuel mimic power monitor, Johnson noise)
- Some are capable of high temperature operation
- All applicable in retrofits as well as new plants

- **Radiation-Hardened Electronics**

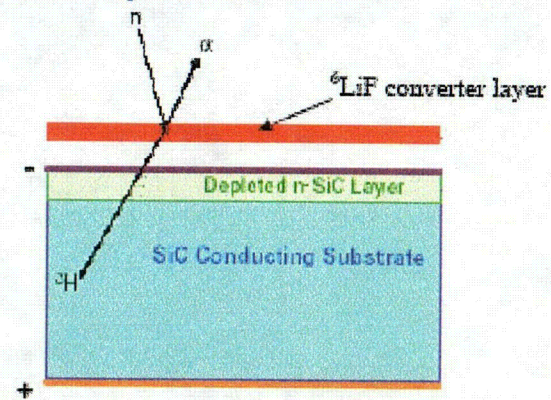
- Progress being made but not yet ready for near-term application
- Considerable effort is being expended in rad-hard IC development for space reactor applications
- Warrants monitoring in periodic surveys

Summary of Findings in Sensors and Measurement Systems Focus Area

Silicon carbide flux monitor may become commercially available in the near term

- Can combine the functions of current three-flux monitors into a single system
- Can improve operating and safety margins
- Important parameters such as drift, accuracy, repeatability and degradation over time, were not available for detailed review
- Should continue to be monitored

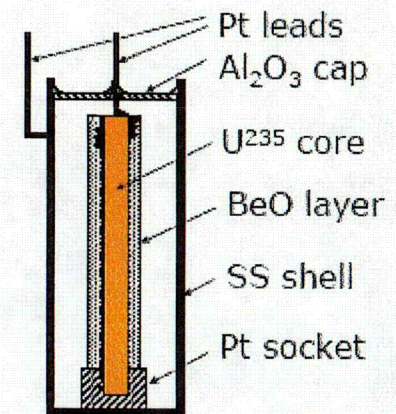
Detection of neutrons via charged particle production by the ${}^6\text{Li}(n, \alpha)$ reaction in a converter foil.



Summary of Findings in Sensors and Measurement Systems Focus Area

Fuel mimic power monitor uses a unique sensing technology, but commercialization may still be a few years away

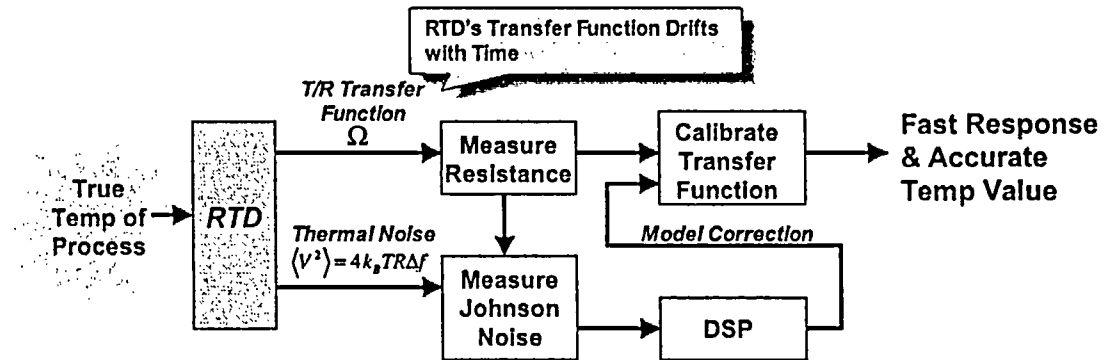
- Provides a direct measurement of the nuclear energy deposited into a fuel mimic mass
- Provides an accurate and direct measurement of reactor power
 - May provide licensees a basis for applying for increase in their licensed operating power level
- Current (second generation) systems have problems with drift
- Commercialization is still some years away and progress should continue to be monitored
- Fuel pellet at steady state $\rightarrow Q_{dep} = Q_{removed} = UA(T_{fuel} - T_{coolant})$
- If a resistance-heating element is placed inside this fuel pellet, then at steady state:



$$Q_{dep, nuclear} + Q_{dep, electrical} = UA (\Delta T) = Constant$$

Summary of Findings in Sensors and Measurement Systems Focus Area

Johnson Noise Thermometry is nearly ready for the nuclear power plant environment.



- **Advantages include:**
 - Inherently drift free operation
 - Insensitivity to the material condition of the detector
 - Immune to contamination and thermo-mechanical response shifts that plague thermocouples and RTDs.
 - These advantages should improve operating as well as safety margins
- **Problems that have hampered commercial utilization in the past:**
 - Long response time because of long integration time required.
- **ORNL Implementation:** Dual mode thermometer, in which the temperature measurement is made with an RTD. The resistance-to-temperature conversion is continuously updated using Johnson noise (on-line, self calibration)
- **Regulatory implication:** required calibration intervals could be relaxed

Summary of Findings in *Radiation-Hardened I&C Technology* Focus Area

- **Advances continue to be made in rad-hard I&C technology that will facilitate introduction of smart transmitters into containment in the near future**
 - Use of technologies such as silicon-on-insulator (SOI)
 - Integration of chalcogenide material with radiation-hardened CMOS process to produce memory arrays
- **Most advances are driven by space applications**
 - Trip modular redundant processing
 - Use of advanced error-corrected dynamic RAMs
 - Monitoring of progress in rad-hard I&C applications in space should continue
- **Nanotriodes are not likely to be deployed in NPPs in the near future. But progress should be followed, given that they could eventually enable smart sensors to migrate into the most inhospitable areas of the plant**
 - It is basically a re-invention of the vacuum tube on a miniature scale
 - Average density of nanotriodes on a silicon wafer is of the order of 10^9 per cm^2 , comparable to the density of MOS transistors
 - Nanotriodes are advantageous over MOS devices in radiation resistance and temperature tolerance
 - Current problem areas include longevity and reproducibility

Next Steps: We Are Currently Evaluating the Path Forward for the Emerging Technologies Project

- **Possibilities Include:**
 - Updates every three years
 - Selection of one focus area (e.g., rad-hard electronics) for detailed treatment, OR
 - Review for experience and trends with advanced I&C systems in other industries that have some relevance for nuclear power applications.
 - In effect, look at advanced I&C architectures and the underlying digital technology in the process industry, fossil power industry and other industrial applications.



Wireless Technology (3.5.6)

Advisory Committee on Reactor Safeguards Digital Instrumentation and Control Subcommittee

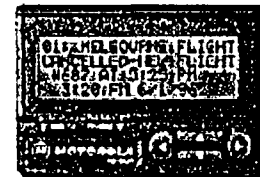
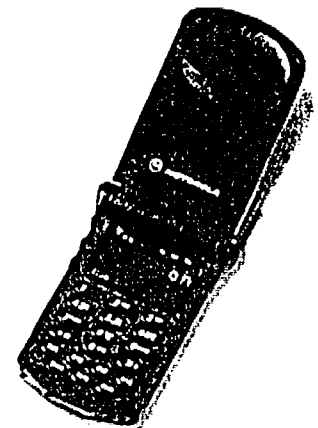
October 21, 2005

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NRC Job Code Y6475 Is Developing the Technical Basis for Implementing Wireless Systems in NPPs

- Impending migration of wireless systems is expected
 - Wireless communications (audio and video)
 - Wireless data systems
- Wireless systems can enhance efficiency
 - Improve general operational awareness
 - Monitor operations in remote areas
 - Increase mobility and flexibility of plant personnel
- Wireless systems have the potential to cause safety problems
 - Cyber security breaches
 - EMI/RFI
 - Intermittent availability



Project Plan Encompasses a Systematic Evaluation of the Implementation of Wireless Systems in NPPs

- Phase 1 — Complete
 - Identify and assess the state of wireless systems
 - Investigate deployment issues associated with wireless systems
- Phase 2 — On-going
 - Conduct confirmatory research to validate findings
 - Establish the technical basis for regulatory position



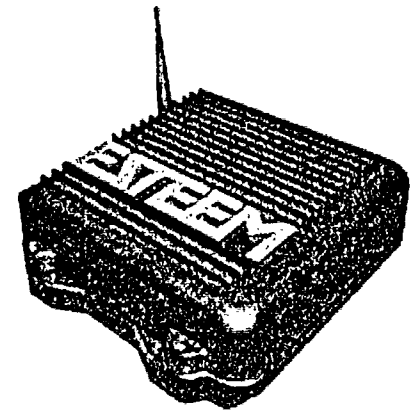
Distinctive Wireless Technology Features Were Used to Distinguish Between Wireless Products

- ❑ Unlicensed vs licensed frequency bands
- ❑ Network topology
- ❑ Network coverage
- ❑ Output power
- ❑ Throughput vs bandwidth
- ❑ Open standards vs proprietary protocols
- ❑ Type of modulation employed

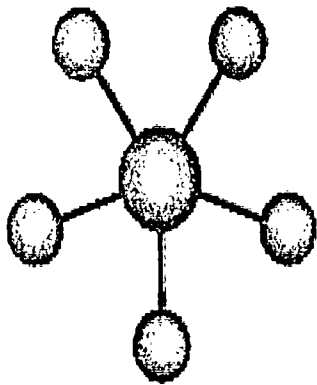


Frequency Band Selection Impacts Wireless Equipment Options

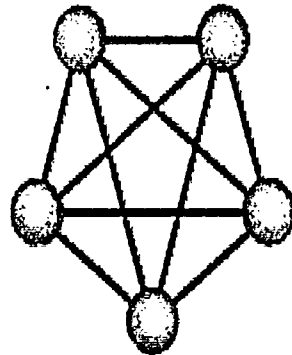
- Unlicensed frequency bands
 - Obey certain power and modulation constraints
 - Cannot interfere with operation of other equipment
 - Bands of choice for many network manufacturers
- Licensed frequency bands
 - Use portion of RF spectrum designated for equipment by spectrum management organizations
 - Pay licensing fee
 - Bands of choice for many RF modem vendors



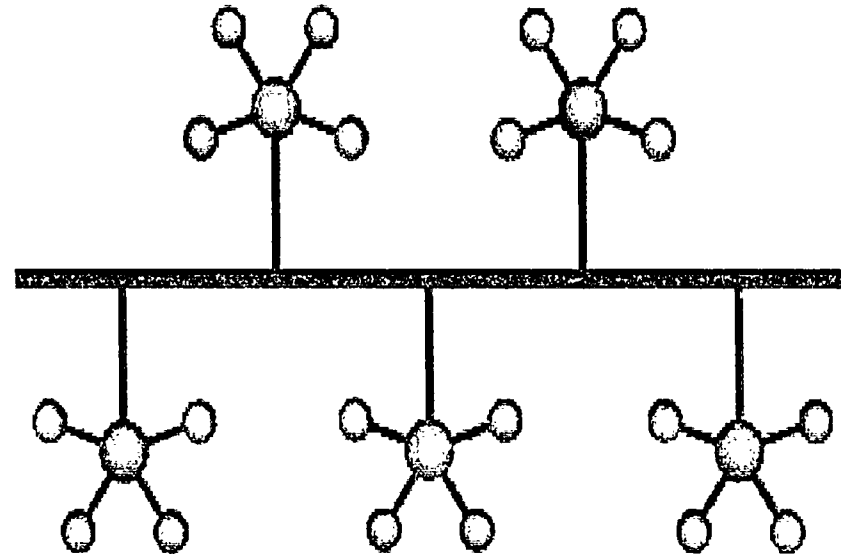
Topology Is Influenced By the Size and Complexity of the Network



Star network



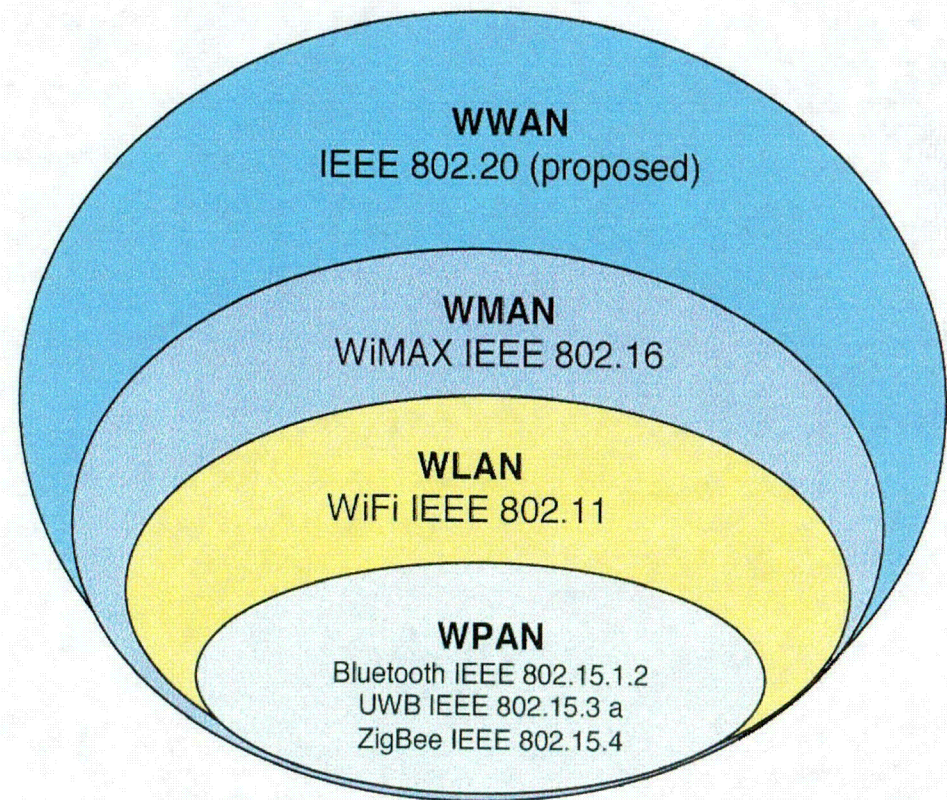
Mesh network



Tree network

Specific Area of Coverage Is Typically Targeted By the Type of Network

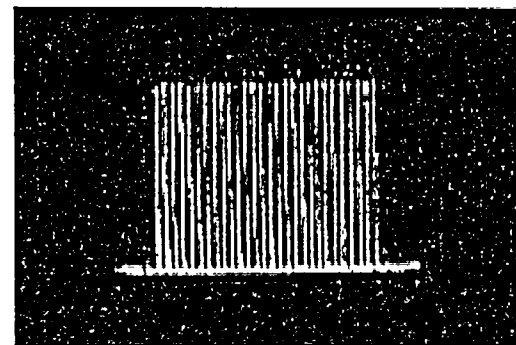
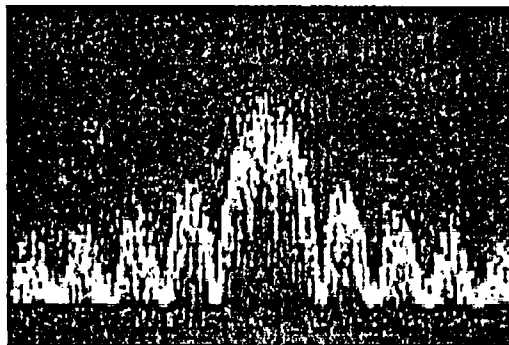
- ❑ Personal area network (PAN) – tens of meters
- ❑ Local area network (LAN) – hundreds of meters
- ❑ Metropolitan/wide area network (MAN/WAN) - kilometers



Wireless Products Employ Varying Modulation Techniques

- Frequency hopping spread spectrum (FHSS) — uses narrow portions of the RF spectrum at one instance and hops to new frequencies 100's to 1000's of times a second
- Direct sequence spread spectrum (DSSS) — spreads the energy of the transmission signal over a wider band so that energy density is lower
- Orthogonal frequency division multiplexing (OFDM) — splits up frequency band for multiple simultaneous transmissions

DSSS



FHSS
OFDM

Wireless Products Are Influenced By Wireless Standards

Standard	OFDM	FHSS	DSSS	GHz	Size	Range	Maximum Mb/s
802.15		x		2.45	PAN	10s of meters	0.7
802.16b	x			5	MAN	kilometers	54
802.11		x	x	2.45	LAN	100s of meters	2
802.11a	x			5	LAN	100s of meters	54
802.11b		x	x	2.45	LAN	100s of meters	11
802.11g	x		x	2.45	LAN	100s of meters	54

Systematic Implementation Approach Is Important When Deploying Wireless Systems

- ❑ Identify the type of wireless system to be deployed
- ❑ Conduct RF compatibility analysis
- ❑ Plan locations of transmitters
- ❑ Define desired coverage area and develop a site analysis



Deployment Issues Associated With Implementing Wireless Systems in NPPs Were Investigated

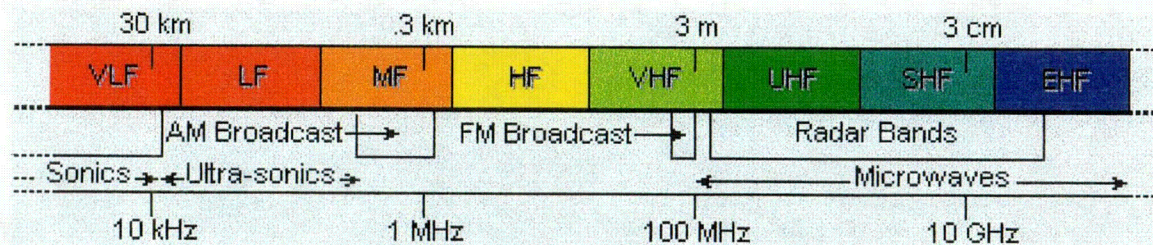
- ❑ EMI/RFI effects
- ❑ Existing wireless products
- ❑ Network security
- ❑ Installation practices
- ❑ Impact of emerging technologies



Key Issues Associated With Deploying Wireless Systems Were Identified

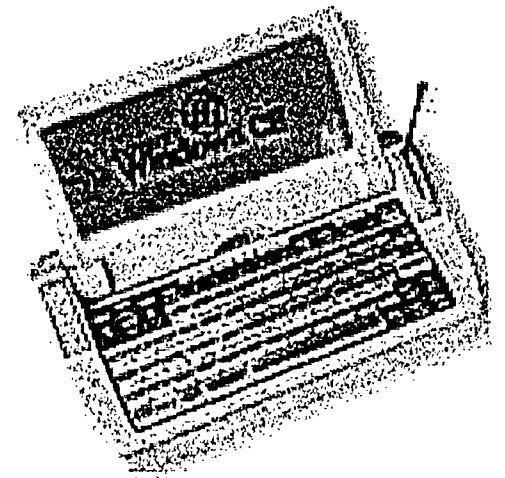
EMI/RFI Effects Could Impact Digital I&C Safety Functions Linked to Wireless Devices

- ❑ Occurrence of interference between 802.11 & Bluetooth devices has been documented
- ❑ 24 of 79 Bluetooth channels were found to be susceptible to interference from single operable 802.11b network
- ❑ Bluetooth interference with 802.11g networks is similar



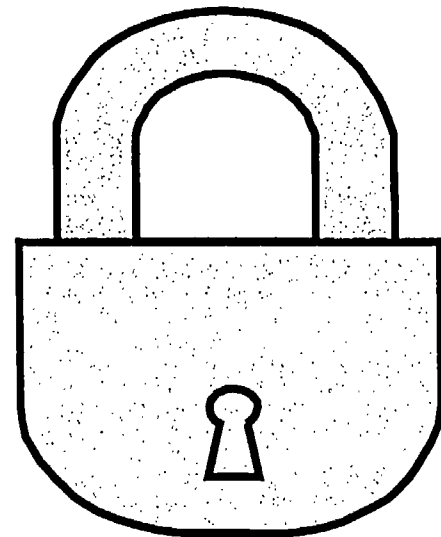
Security Of Information Must Be Considered

- ❑ Wireless communications are not confined to a conductive path that can be easily seen
- ❑ Signals can be intercepted at locations that may not be obvious
- ❑ Signals may propagate with sufficient field strength beyond set boundaries
- ❑ Monitoring access control is more difficult for wireless communications



A Layered Approach to Security Measures Is Recommended to Defend Wireless Networks

- ❑ Password protection
- ❑ Encryption
- ❑ Administrative controls
- ❑ Network diversity / segmentation
- ❑ Firewalls
- ❑ Access point management
- ❑ Signal strength management

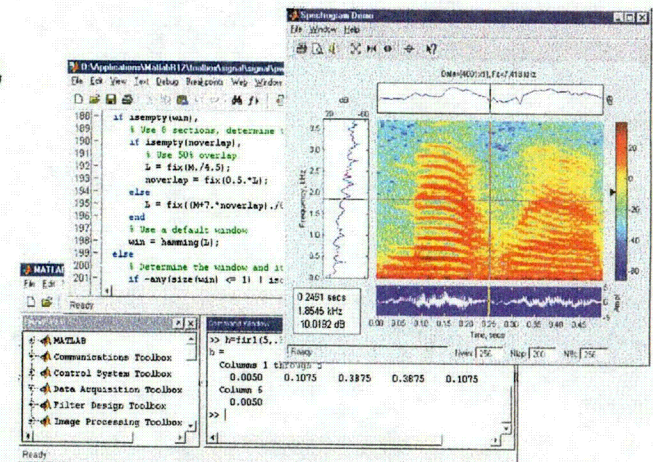


Certain Conclusions Were Derived From the Investigation

- Overall implementation of wireless systems in NPPs will require NRC oversight to ensure safety
- Safety considerations in the nuclear environment will warrant stringent wireless-related security measures
 - Follow-up project will evaluate wireless security measures
- Wireless-based systems have the potential for interference with other plant systems, hence EMI/RFI guidance should be followed
- Prudent use of redundancy may be required to ensure the reliable operation of a wireless system

Confirmatory Research is Now Being Performed to Validate the Impact of the Phase 1 Findings

- Developing wireless communications evaluation tools
 - Mimic the operations of multiple wireless systems in the NPP environment
 - Confirm wide-area RF propagation coverage within critical NPP areas
- Assessing interference issues associated with co-locating wireless technologies



Results of Project Are Progressing As Planned

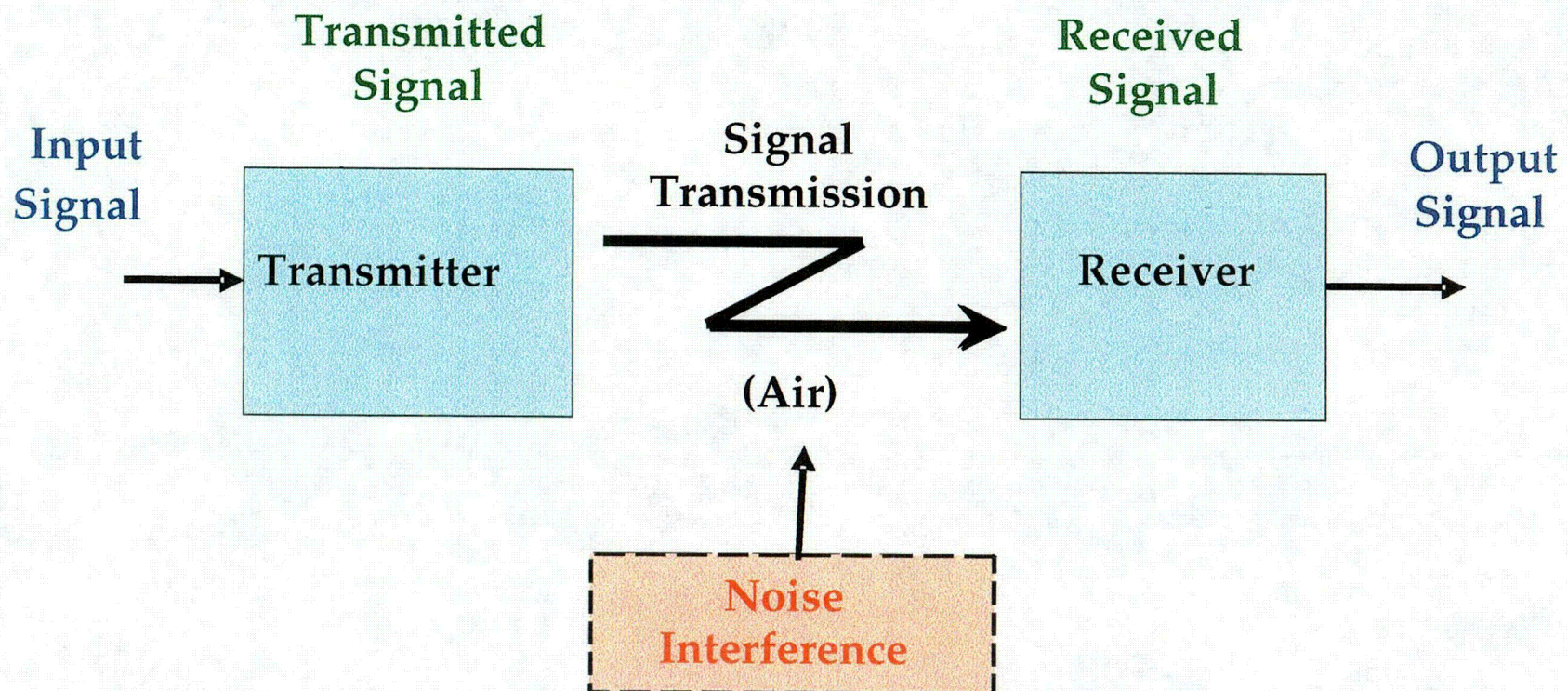
- NUREG/CR-6882, *Assessment of Wireless Technologies and Their Application at Nuclear Power Plants*, was completed in July 2005 — reports on Phase 1 effort
- 1st Draft of NUREG/CR-XXXX, *Assessment of Industrial Wireless Protocols in the Nuclear Power Plant Environment*, has been completed — reports on modeling and simulation progress to date

NRC Job Code Y6475 Will Continue Through FY2007

- Continue confirmatory research on the simulation of wireless systems**
- Complete development of wireless communications evaluation tools suitable for use in NRC reviews**
- Complete NUREG/CR to document the development of wireless communications evaluation tools**
- Develop training materials for wireless communications evaluation tools**
- Establish criteria for regulatory guidance based on the research findings**

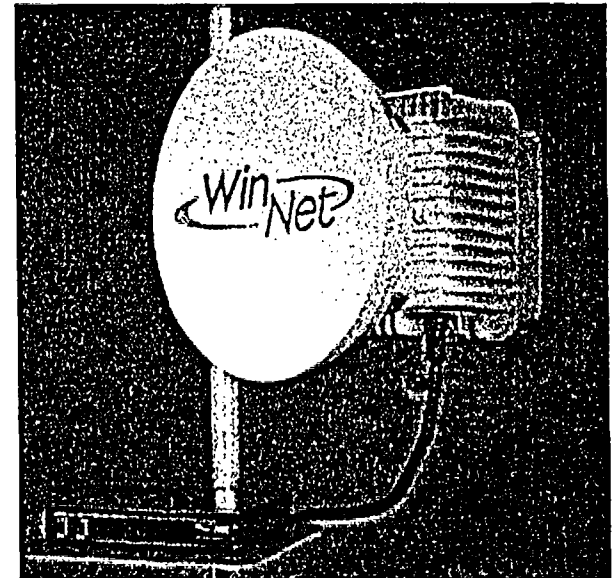
Backup Slides

Essential Elements of a Wireless System Are the Transmitter, a Transmission Path, and the Receiver

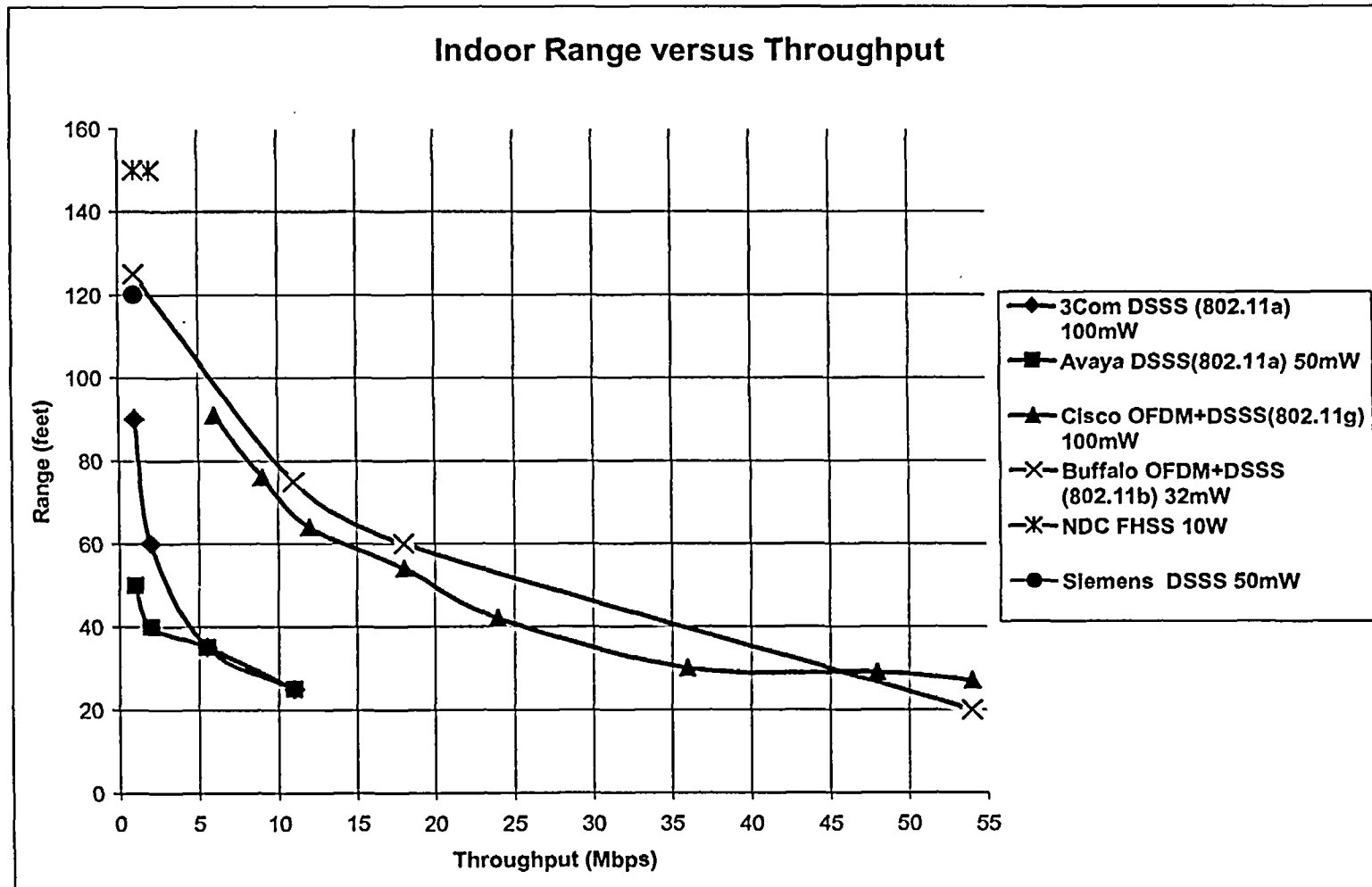


State of Wireless Technologies Presently Available Were Identified and Assessed

- Searched various information sources
 - Web sites
 - Technical databases
 - Technical conferences/trade shows
- Collected extensive information on wireless technologies and identified distinctive product features
- Collaborated with EPRI Wireless Working Group

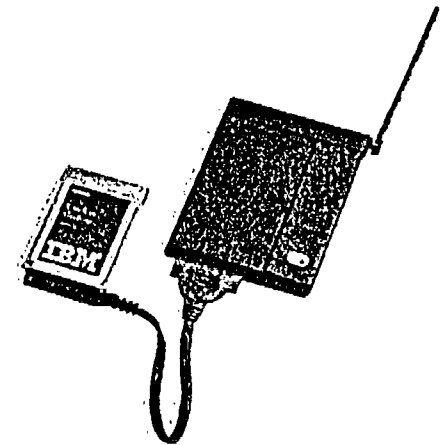


For a Given Wireless Product Output Power Level, Throughput Depends On Bandwidth



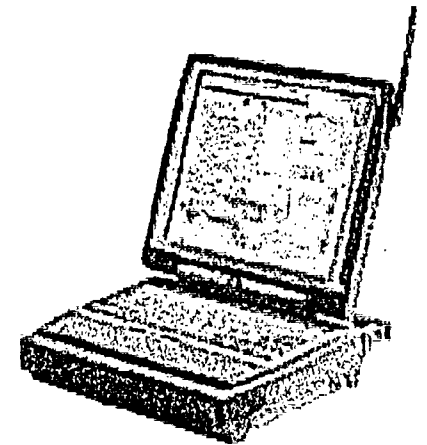
Proprietary vs Non-proprietary Protocol Can Be a Longevity Issue

- ❑ Implementation of proprietary protocol can lead to a condition where entire system is dependent on longevity and commitment to a single product line
- ❑ Has become common to choose non-proprietary (or open-standard) protocol systems that can be supported by multiple vendors and upgraded as technologies evolve
- ❑ “Ethernet” implementation of IEEE 802 standard has proven the validity of open-standard approach



Modulation Techniques Are Selected for Practicality and Robustness

- ❑ FHSS is often easier to set up and has better range than DSSS in some situations, but offers little improvement in improving electromagnetic compatibility (EMC)
- ❑ DSSS can be more complex to install, but is well suited for medium-bandwidth applications and greatly reduces the probability of upsetting other electronic devices
- ❑ OFDM is recommended for high-bandwidth (100's of Mbps) point to point connections, but does not typically improve EMC



Emerging Technologies Have to Be Considered When Planning for Potential Upgrades

- ❑ Ultra-wideband (UWB) technology for short distance communications—IEEE 802.15.3
- ❑ Mobile broadband wireless access for wide area communications—IEEE 802.20
- ❑ Voice over internet protocol (IP)
- ❑ Quality of service (QoS) improvements—IEEE 802.11e
- ❑ Multiple input-multiple output (MIMO) technology—IEEE 802.11n

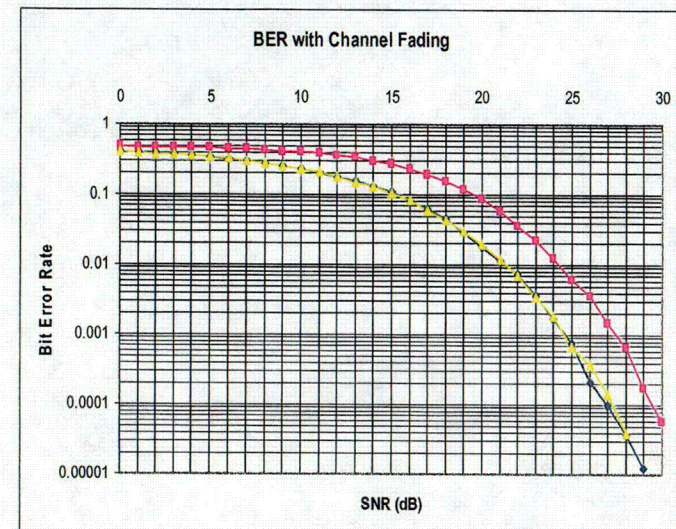
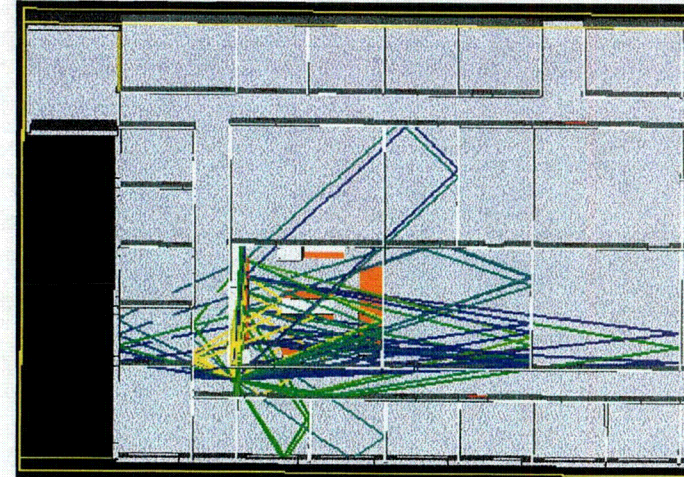
Evaluation Tools Are Being Developed Using Simulation Packages

Wireless Insite

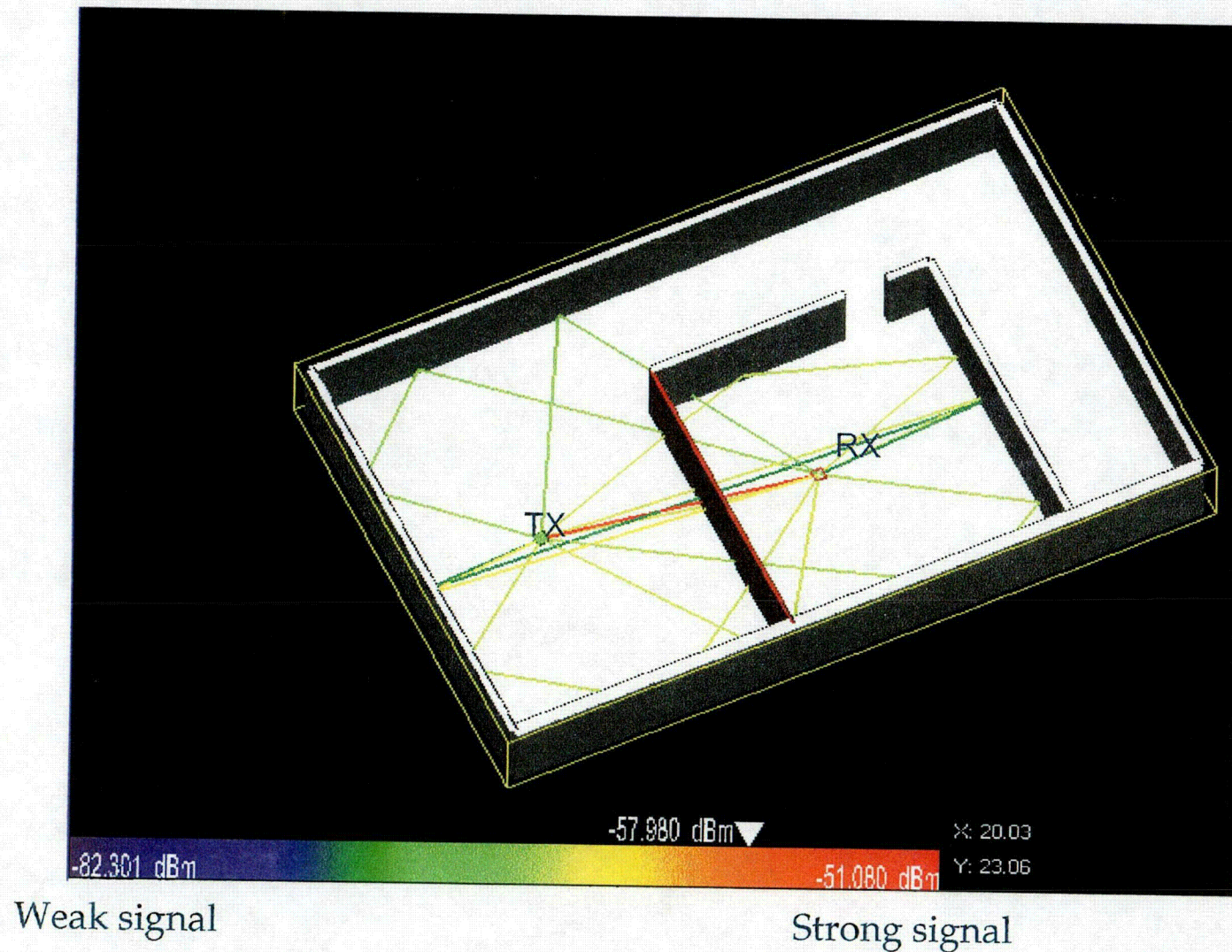
- Input CAD drawing of area
- Place receiver and transmitters
- Calculate propagation effects on transmitted signal and interfering signals through ray tracing techniques

Matlab

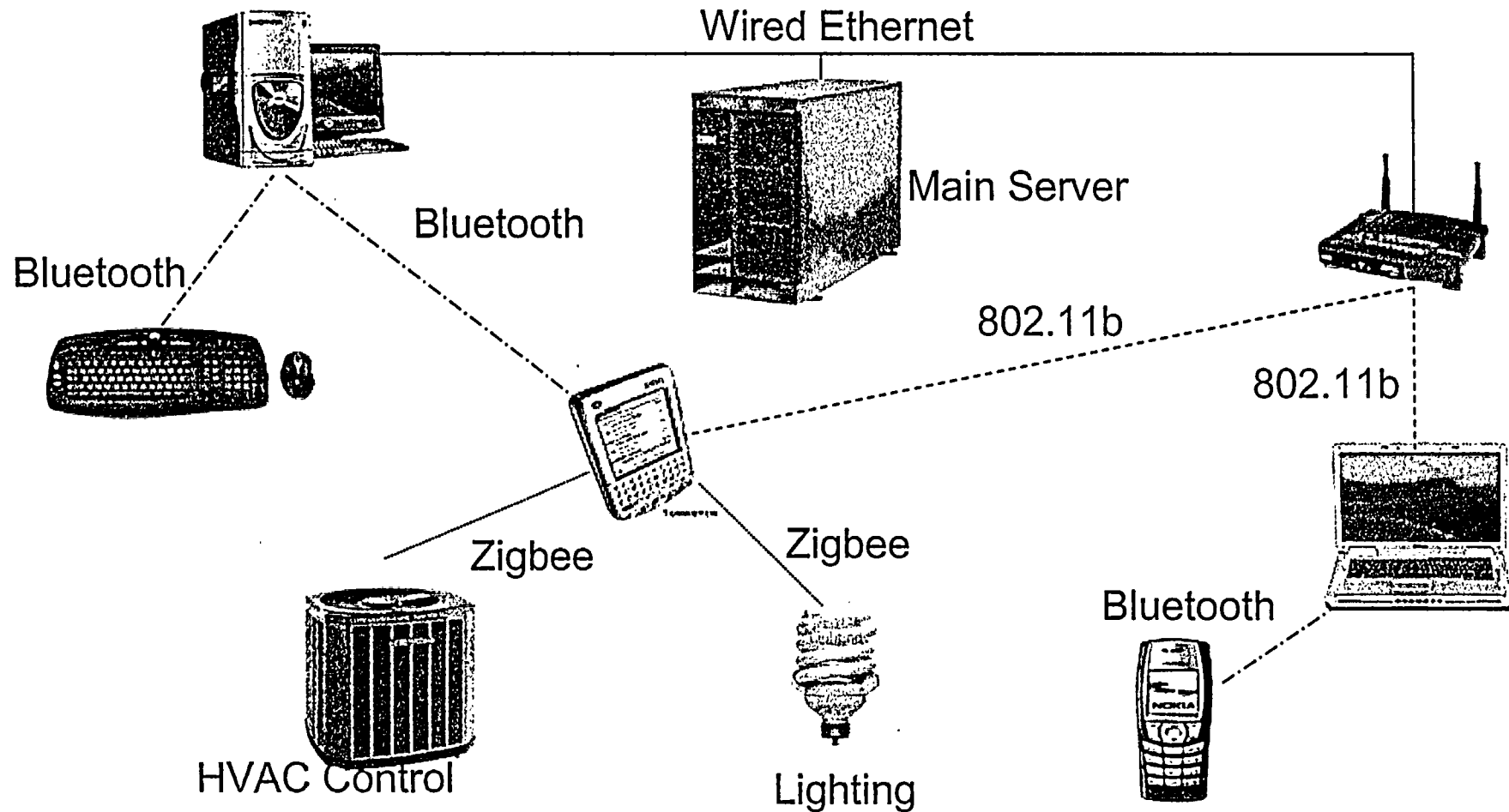
- Combine transmitted signal with interfering signals
- Demodulate the received signal
- Determine if transmitted signal has successfully been received within acceptable threshold



Case Studies Are Conducted Using Wireless Insite



MATLAB Modeling Set Includes Numerous Wireless Devices





On-Line Sensor Calibration Monitoring Challenges and Effective Uncertainty Estimation

Advisory Committee on Reactor Safeguards
Digital Instrumentation and Control Subcommittee

October 21, 2005

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Overview

- Background
- Project Objectives
- Modeling Methods
- PEM Toolbox
- Uncertainty Estimation
 - Re-sampling Techniques
 - De-noising Techniques
- Conclusions



Background

- 1995, the NRC published NUREG/CR-6343, "On-Line Testing of Calibration of Process Instrumentation Channels in Nuclear Power Plants". It presented several advantages including
 - a reduction of intrusive, unnecessary field calibrations,
 - the continuous assessment of instrument performance,
 - and early instrument performance degradation detection.
- In 1998, the Electric Power Research Institute (EPRI) submitted Topical Report TR-104965, "On-Line Monitoring of Instrument Channel Performance" for NRC review.
- In June 2000, NRC issued a safety evaluation report (SER) that concluded the generic concept of on-line monitoring (OLM) for calibration interval extension is acceptable and listed 14 requirements that must be addressed in plant specific license amendments.



Background (Cont.)

- The SER did not review or endorse either of the two algorithms addressed in the topical report, but instead, left the choice of algorithm up to the utility.
- EPRI formed the On-Line Monitoring Implementation Users Group in 2001 to demonstrate OLM in multiple applications at several nuclear power plants. Current U.S. nuclear plant participants include Limerick, Salem, Sequoyah, TMI, and V.C. Summer.
- V.C. Summer met with the NRC on March 9, 2005 to discuss the submission of a plant specific license amendment for calibration interval extension.



Potential Challenges

- Assumptions inherent in the methods related to
 - the training data,
 - the predictive models,
 - the uncertainty analysis methods,
 - plant operations.
- Several past topics including
 - Single point monitoring,
 - Common mode failure,
 - Implementation relationship to setpoint calculations,
 - Drift limits.



NRC Research Project

- Objectives
 - Provide an independent review and assessment of the proposed OLM techniques implementation and tools to assist in ongoing reviews regulatory reviews.
- Deliverables
 - NUREG/CR Technical Review of On-line Monitoring Techniques for Performance Assessment: Part I "State of the Art" (Spring 2005)
 - NUREG/CR Technical Review of On-line Monitoring Techniques for Performance Assessment: Part II "Theoretical Issues" (Fall 2005)
 - On-line Instrument Condition Monitoring Tools (Winter 2005)
 - NUREG/CR On-line Instrument Condition Monitoring Tools and Performance Assessment (Summer 2006)



Uncertainty Analysis Methods

- Analytic Methods:
 - Formulas derived from Taylor series expansion.
 - Includes equations for MSET, AANN, AAKR, and NNPLS.
- Monte Carlo based re-sampling methods
 - Latin Hypercube Sampling with wavelet de-noising (Argonne).
 - Conventional Bootstrapping.



Uncertainty Estimation

- Uncertainty estimation is performed by estimating a model's bias and variance.
- Bias measures the systematic error or the error between the expected parameter estimate and its true value.

$$Bias(\hat{\theta}) = E(\hat{\theta}) - \theta$$

- Variance measures the variability of a model's predictions with respect to their expected prediction.

$$Var(\hat{\theta}) = E[\hat{\theta} - E(\hat{\theta})]^2$$

θ = *Parameter value*

$\hat{\theta}$ = *Parameter estimate*



Analytic Variance Estimation

- AAKR and AAMSET variance estimation is based upon the following relationship:

$$\text{var}(\hat{\theta}) = H^T H \cdot \sigma_{\varepsilon}^2$$

$H = \text{Hat Matrix}$
 $\sigma_{\varepsilon}^2 = \text{Noise Variance Estimate}$

- AANN variance is based upon that of a general nonlinear model.

$$\hat{y}_o \pm t_{\alpha/2}^{n-p} \cdot s \sqrt{1 + \bar{f}_o^T [\bar{F}^T \bar{F}]^{-1} \bar{f}_o}$$

- Here, F and f_o are a Jacobian matrix and vector that are commonly calculated during network training, s is an estimate of the sensor noise variance, and t is from Student's t-distribution.

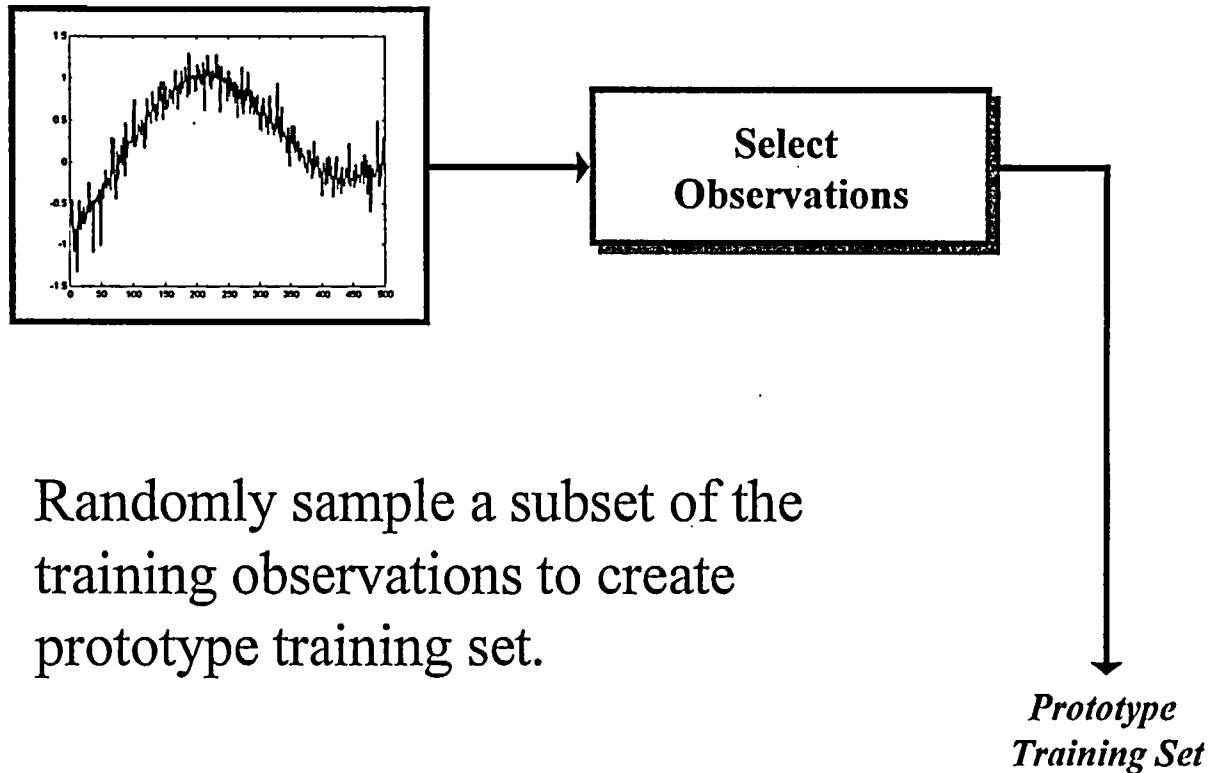


Monte Carlo Uncertainty Estimation

1. Use a random sampling of historical data to create a prototype training set from the original data and build a predictive model,
2. Apply the model to an independent test set,
3. Store the model predictions,
4. Repeat the process until the specified number of iterations have been executed.
5. Following this iterative cycle, the variation of the predictions are used to calculate an estimate of the model's uncertainty.

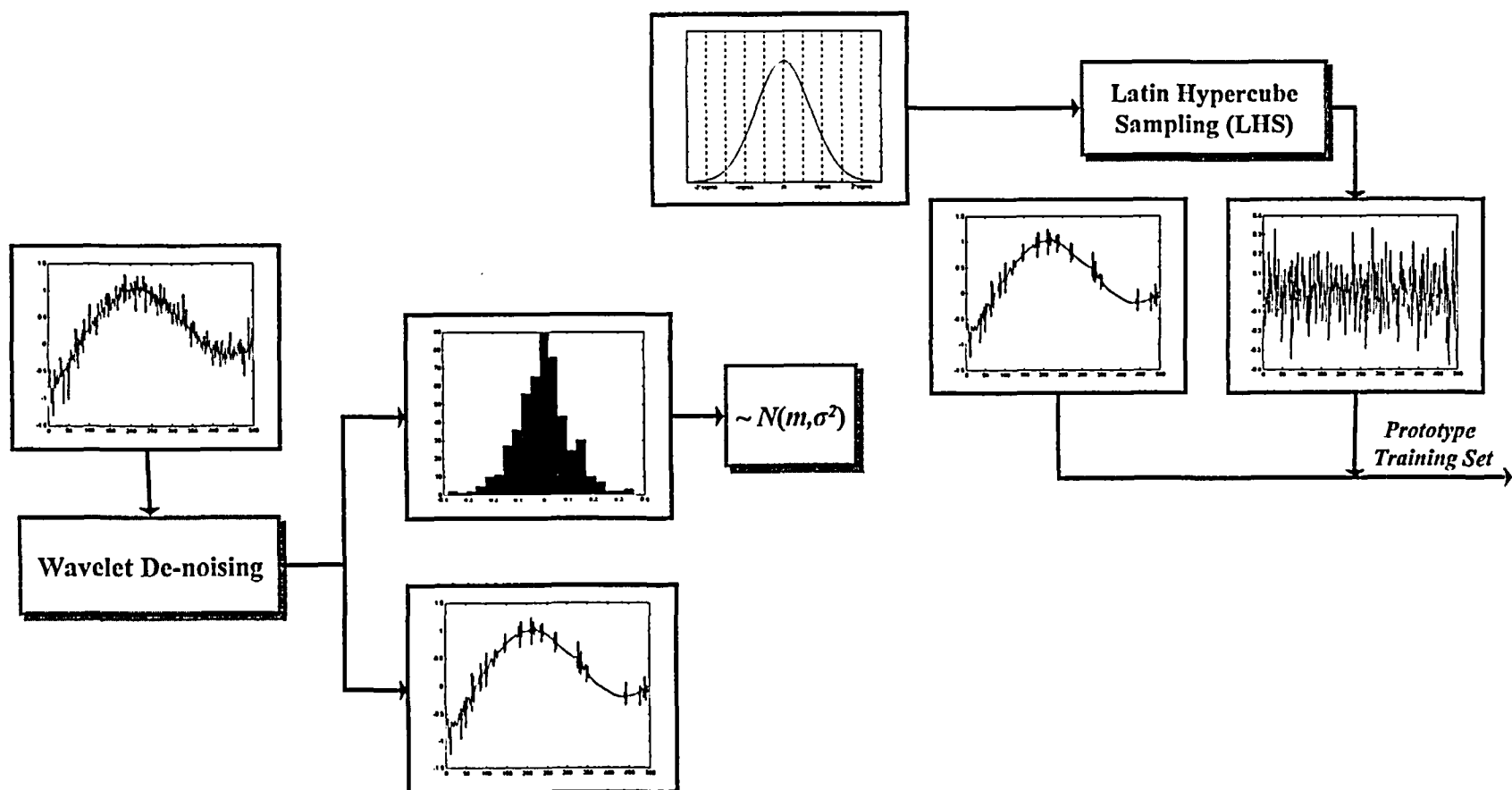


Conventional Bootstrapping





Wavelet De-noising with Latin Hypercube Sampling





Bias Estimation

- Estimating bias requires an estimate of the “true” parameter values.
- An estimate of the “true” parameter values may be obtained through the use of several smoothing techniques:
 - Median filtering
 - Independent Component Analysis (ICA)
 - Wavelet de-noising
- A conservative estimate of a constant bias is then made by calculating a time dependant bias for a set of development data and determining the value that contains 95% of the biases.



True Signal Estimation

- Necessary for Latin Hypercube Sampling
- Necessary for Bias Quantification
- Methods
 - Independent Component Analysis (Ding UT)
 - Only used for redundant sensors.
 - Can decompose into signal, common noise, and independent noise.
 - Wavelet de-noising (Miron ANL)



De-noising comparison results

	ICA	Wavelet	Actual
Expected Noise Mean	-0.002	0.000	0.005
Expected Noise Variance	0.122	0.050	0.092
Expected Squared Error	0.047	0.050	0.000
Fractional Variance Reduction	0.239	0.097	0.147
Expected Correlation	0.307	0.016	-0.028
Expected Correlation (smoothed version)	0.018	0.002	-0.049



Process Equipment Monitoring (PEM) Toolbox

- Objective: The objective is to develop a set of tools that is functionally equivalent to the commercial tools being marketed for PEM so that the techniques and their assumptions can be experimentally verified.
- The beta version of the PEM Toolbox consists of
 - A MATLAB Toolbox with over 80 functions, 7500 lines of code, and 400 pages of documentation.
 - HELP Functions: On-line HTML-based help functions have been written for the toolbox.
 - Documentation:
 1. **User's Guide** – toolbox architecture, structure variable definitions, function reference, settings reference, and definitions.
 2. **Tutorial** – detailed tutorial stepping through the application of each of the toolbox functions for process equipment monitoring.
 3. **Technical Reference** – detailed discussion of modeling techniques and other technical aspects of the toolbox functions, such as derivations and method descriptions/comparisons.



Automated PEM Functions

1. Data Manipulation

- File and workspace data acquisition
- Outlier detection and correction

2. Model Development

- Optimal variable grouping
- Multivariate model optimization

3. Prediction

- Autoassociative kernel regression (AAKR)
- Autoassociative MSET (AAMSET)
- Autoassociative neural networks (AANN)

4. Model Performance Evaluation

- Accuracy
- Robustness
- Spill-over

5. Uncertainty Estimation

- Analytic
- Monte Carlo

6. Fault Detection

- Prediction interval coverage monitoring
- Error uncertainty limit monitoring
- Sequential probability ratio test

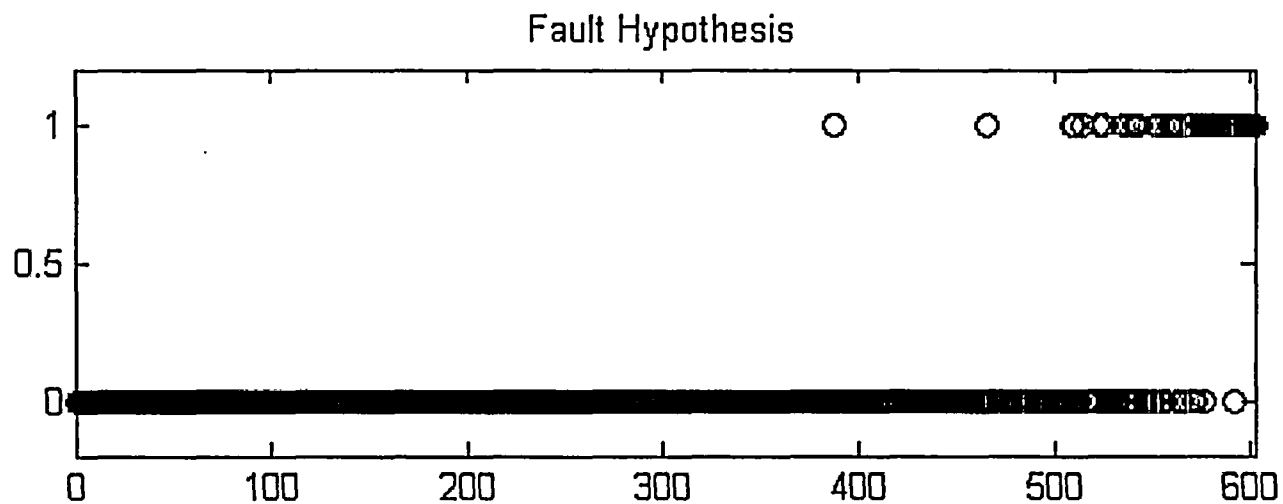
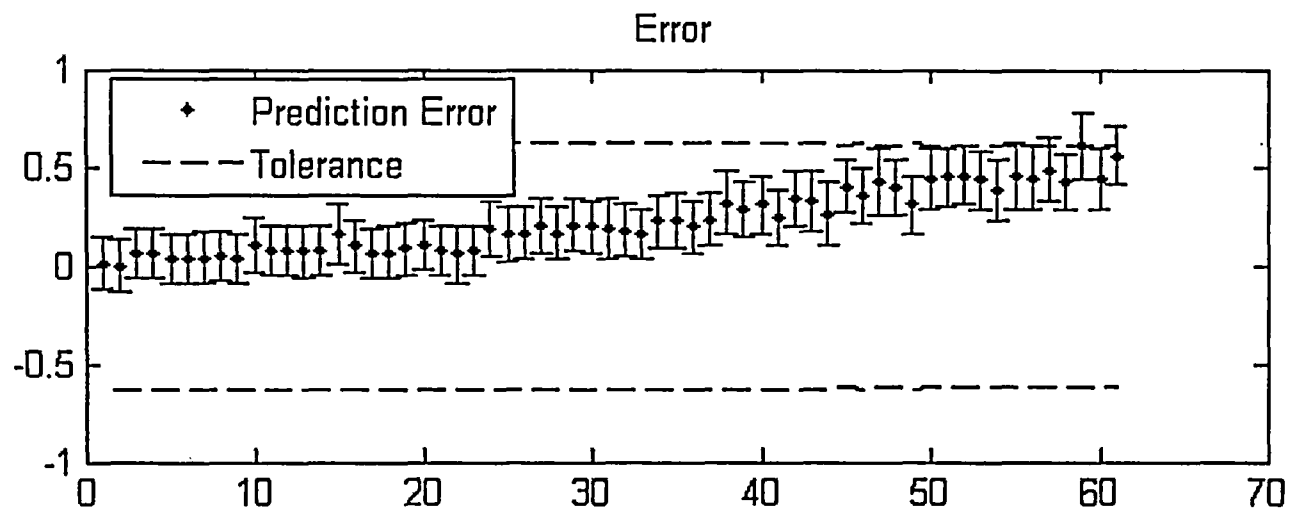


Error Uncertainty Limit Monitoring (EULM)

- This method of fault detection monitors the residual between a sensor prediction and its measured value, and takes into consideration the prediction uncertainty.
- A sensor is identified as faulted when the sum of its error and uncertainty exceeds a specified tolerance.
- This detection method is most generally applied to sensor calibration validation tasks, where a sensor is allowed to drift a certain percentage of its nominal value.



EULM Example -- fdetect



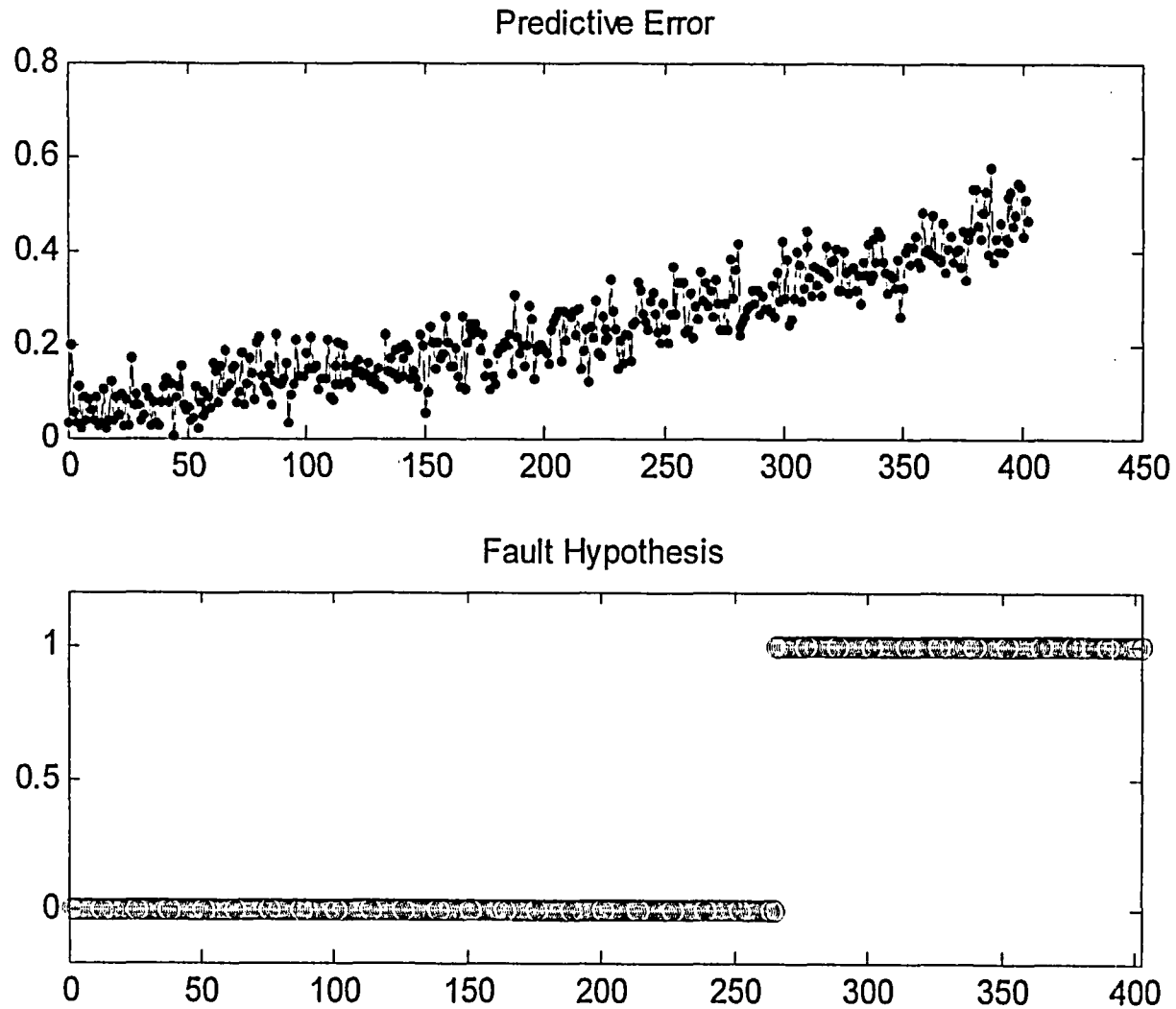


Sequential Probability Ratio Test (SPRT)

- This fault detection method examines an error distribution and detects changes in its mean and variance.
- This method determines if it is statistically more likely for a sensor to have a drift of zero or for it to have some faulted drift value.
- It is a sequential method developed in the 40s and applied to sensor calibration monitoring in the 90s by ANL.



SPRT Example -- fdetect





Conclusions

- The work has culminated in the production of a NRC NUREG/CR that will serve as a reference for reviewers, developers and users of OLM methods.
- The first draft of a second NUREG/CR has been developed that incorporates recent research results:
 - Development of methods to predict bias and variance.
 - Derivation and application of analytical uncertainty estimation techniques.
 - Comparison of bootstrap and LHS Monte Carlo methods.
 - Both methods produce accurate uncertainty estimations.
 - The computational burden and number of assumptions of the wavelet de-noising with LHS technique make it less desirable.
 - De-Noising is necessary for bias computation.
 - Comparison of Wavelet and ICA de-noising techniques
 - Wavelet has many assumptions that are difficult to validate.
 - ICA is quicker but can only be applied to redundant sensors.



Conclusions (Cont)

- The PEM Toolbox was developed and is being used to validate the proposed OLM techniques.
 - Its modeling techniques produces results similar to that of commercial software.
 - Nuclear plant data is being used to validate the results of the second NUREG/CR.
 - Limiting cases are being used to uncover hidden problems not covered in the current assumptions.