UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

June 13, 2006

MEMORANDUM TO: ACRS Members

FROM: Eric A. Thornsbury, ACRS Senior Staff Engineer **/RA/**

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEE ON RELIABILITY & PROBABILISTIC RISK ASSESSMENT, APRIL 20-21, 2006 - ROCKVILLE, MARYLAND

The minutes of the subject meeting, issued May 19, 2006, have been certified as the official record of the proceedings of that meeting. A copy of the certified minutes is attached.

Attachment: As stated

electronic cc: J. Larkins
A. Thadani
S. Duraiswamy
M. Snodderly

UNITED STATES
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WASHINGTON, DC 20555 - 0001

MEMORANDUM TO: Eric A. Thornsbury, ACRS Senior Staff Engineer

FROM: George E. Apostolakis, Chairman
Reliability & Probabilistic Risk Assessment Subcommittee

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEE ON RELIABILITY & PROBABILISTIC RISK ASSESSMENT, APRIL 20-21, 2006 - ROCKVILLE, MARYLAND

I do hereby certify that, to the best of my knowledge and belief, the minutes of the subject meeting on April 20-21, 2006, are an accurate record of the proceedings for that meeting.

/RA/ 6/1/06
George E. Apostolakis Date
Subcommittee Chairman

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

July 11, 2006

MEMORANDUM TO: Mario V. Bonaca, Chairman
Human Factors Subcommittee

George E. Apostolakis, Chairman
Reliability & Probabilistic Risk Assessment Subcommittee

FROM: Eric A. Thornsbury, ACRS Senior Staff Engineer **/RA/**

SUBJECT: WORKING COPY OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEES ON HUMAN FACTORS AND RELIABILITY & PROBABILISTIC RISK ASSESSMENT, JUNE 28, 2006 - ROCKVILLE, MARYLAND

A working copy of the minutes for the subject meeting is attached for your review. Please review and comment on them. If you are satisfied with these minutes, please sign, date, and return the attached certification letter.

Attachment: Minutes (DRAFT)

cc: Human Factors Subcommittee Members
Reliability & Probabilistic Risk Assessment Subcommittee Members
J. Larkins
S. Duraiswamy
M. Snodderly
C. Santos

Issued: May 19, 2006
Certified: June 1, 2006

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE ACRS SUBCOMMITTEE ON RELIABILITY & PROBABILISTIC RISK ASSESSMENT
MEETING MINUTES - APRIL 20-21, 2006
ROCKVILLE, MARYLAND

INTRODUCTION

The ACRS Subcommittee on Reliability & Probabilistic Risk Assessment held a meeting on April 20-21, 2006, in Room T-2B1, 11545 Rockville Pike, Rockville, MD. The purpose of this meeting was to discuss the probabilistic risk assessment (PRA) for the Economic Simplified Boiling Water Reactor (ESBWR), an advanced design from General Electric (GE) that is in the process of design certification. Eric Thornsbury was the Designated Federal Official for this meeting. The Committee received no written comments or requests for time to make oral statements from the public. The Subcommittee Chairman convened the meeting at 8:30 a.m. on April 20, 2006, recessed at 5:10 p.m., reconvened at 8:30 a.m. on April 21, 2006, and adjourned at 11:30 a.m..

ATTENDEES

ACRS

G. Apostolakis, Subcommittee Chairman
S. Armijo, Member
M. Bonaca, Member
R. Denning, Member
T. Kress, Member
O. Maynard, Member
J. Sieber, Member
W. Shack, Member
G. Wallis, Member
E. Thornsbury, Designated Federal Official

Principal Speakers

A. Cubbage, NRC/NRR
T. Theofanous, UCSB
M. Khatib-Rahbar, ERI
R. Wachowiak, GE
S. Bhatt, GE

Other members of the staff and public attended this meeting. A complete list of attendees is in the ACRS Office File and is available upon request. The presentation slides and handouts used during the meeting are attached to the office copy of these minutes.

OPENING REMARKS BY CHAIRMAN APOSTOLAKIS

George Apostolakis, Chairman of the ACRS Subcommittee on Reliability & Probabilistic Risk Assessment, convened the meeting at 8:30 a.m. Dr. Apostolakis stated that the purpose of this meeting was to begin the Committee's review of the ESBWR probabilistic risk assessment. He said the Subcommittee would gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee.

The rules for participation in the meeting were announced as part of the notice of the meeting published in the Federal Register on April 4, 2006. Dr. Apostolakis acknowledged that the Committee had received no written comments or requests for time to make oral statements.

DISCUSSION OF AGENDA ITEMS

Introduction

Ms. Amy Cubbage, ESBWR Senior Project Manager in the Office of Nuclear Reactor Regulation (NRR), began the presentations. Ms. Cubbage provided a brief discussion of the status and schedule for the ESBWR design certification. The design certification application was submitted in August 2005 and supplemented in September and October of the same year. In December 2005, the application was officially docketed. She noted that the staff has issued preliminary requests for additional information (RAIs) regarding the probabilistic risk assessment and severe accident analysis. The vendor is currently in the process of responding to the RAIs and creating Revision 1 to the PRA.

The schedule for the design certification calls for the NRC staff to issue RAIs through October 2006, with responses from GE finished by November 2006. The staff plans to issue its Safety Evaluation Report (SER) with open items in October 2007. The schedule assumes an additional 15 months for the staff to issue supplemental SERs to address the open items. The final rulemaking process will take approximately 12 months following the resolution of all open items.

ESBWR Risk Management Overview

Mr. David Hinds, GE, made the introductions for GE and noted that the vendor developed the PRA in parallel with the overall design process so that they could incorporate insights from the PRA into the plant design. He introduced Rick Wachowiak, the PRA lead for the ESBWR, who would be leading most of the presentations. He also introduced Sid Bhatt, Alan Beard, and Theo Theofanous, who would be supporting Mr. Wachowiak and providing some of the presentations. He then turned the meeting over to Mr. Wachowiak to begin the formal presentations.

Mr. Wachowiak outlined the purposes of the meeting: to discuss the strategy for risk management in the ESBWR design, to demonstrate how the ESBWR design prevents and mitigates severe accident risk, and to examine the use of PRA to guide the design and licensing of the new plant design. He then described the program goals for the PRA during the design certification phase and the scope of the ESBWR PRA. The PRA covers internal events at full power in Levels 1, 2, & 3, internal events during shutdown, and external events (fire, flood, high winds, and seismic) in Level 1 for both full power and shutdown.

Mr. Wachowiak described how the ESBWR builds on the classic design principles of defense-in-depth by explicitly considering severe accident issues. This allows the designers to address common cause failures and minimize their effect. Mr. Wachowiak discussed how the PRA was used as a design tool. The PRA provided a systematic means for finding and eliminating vulnerabilities in the design, though its effectiveness is somewhat limited by the availability of complete information during the design phase. He stated that though the PRA is imperfect, it is better than no tool at all if applied in a prudent manner.

Mr. Wachowiak then used a figure to describe how the PRA evolves along with the design of the plant, from the conceptual phase to detailed design and on to the operating plant. At this time, the PRA is somewhere between the initial design basis phase and the detailed design, which is appropriate for licensing the plant, and includes the major components, quantification of the PRA (though some gaps remain), resolution of defense-in-depth issues, and addressing of system level vulnerabilities. He concluded this session by discussing GE's vision of the evolution of the capability of the PRA as the design leads to construction and how the current risk management program successfully meets its goals.

<u>Comments and Observations From the Subcommittee Members</u>

- Dr. Denning asked which risk goals the PRA is trying to meet. Mr. Wachowiak confirmed that these were the quantitative health objectives, in the form of core damage frequency (CDF) and large early release frequency (LERF). Dr. Denning asked if GE has more stringent goals internally. Mr. Wachowiak answered affirmatively, stating that their design goal is a CDF of 10^{-7} for known events.

- Dr. Apostolakis stated that the PRA cannot yet demonstrate that it meets the goals, since it is incomplete, though it is a good sign to be orders of magnitude below the goals. Mr. Wachowiak agreed, stating that it does demonstrate that the plant meets the goals for the things we know about.

- Dr. Wallis asked if the PRA includes human errors of commission. Mr. Wachowiak said no, though they recognize that though the plant is designed for no human actions for 72 hours, that doesn't mean no actions will occur. He added that the plant design is such that it should move itself back into a stable state following a human error.

- Dr. Apostolakis asked for an example of how the PRA was used to influence the design. Mr. Armijo echoed that question, asking if it was really a result of the PRA. Mr. Wachowiak answered that many of the design improvements did come from the PRA, though he noted that the designers probably would have gotten the diversity requirements elsewhere in the design process. The PRA served to bring these requirements out more explicitly, for example, in the diverse instrumentation and control systems.

- Mr. Sieber asked what was meant by diversity in the instrumentation and control systems (e.g., common software). Mr. Wachowiak stated that the design addresses all such diversity issues, including the hardware platform, vendors, and operating systems. He recognized that some overlap may still exist. Mr. Hinds added that they are using design acceptance criteria for the design certification so that they can maintain some flexibility in this area.

- Dr. Denning asked about the effect of addressing severe accidents during the design on the regulatory treatment of some systems. Mr. Hinds replied that these systems are important to safety, so they need high reliability, though that reliability doesn't necessarily have to be at the same level as the front-line systems. Mr. Wachowiak noted that the BiMAC system falls into this category under RTNSS (regulatory treatment of non-safety systems).

Internal Events Risk Management

Mr. Wachowiak continued by presenting the ESBWR internal events and severe accident prevention risk management program. The ESBWR design uses passive safety systems as its core protection system. These passive systems are backed up by active asset-protection systems, both of which rely on diverse support systems. Each core damage prevention function can be accomplished by either passive and active systems.

Mr. Wachowiak then described the passive and active systems that perform each function: reactivity control, pressure control, high-pressure inventory control, low-pressure inventory control, depressurization, and decay heat removal. He provided an example of a diverse control system for operation of the gravity-driven cooling system with depressurization valves. He also walked through two event trees from the PRA to describe the sequence of protection functions.

Mr. Wachowiak described the initiating events used in the PRA and the sources of information used to quantify them. In general, the initiating event frequencies are based on data from operating plants, but some contributors were eliminated that do not apply to the ESBWR. Mr. Wachowiak also described how GE used generic basic event failure rates, but increased it for equipment which must operate in a harsh environment or which will have a longer test interval in the ESBWR.

Mr. Wachowiak continued by explaining the approach used for human actions. GE used a simplified approach to address both pre-accident and post-accident errors. They used screening values in the PRA and did not credit any repair actions other than recovery of offsite power. Mr. Wachowiak also described how the PRA uses hand calculations, TRACG calculations, and/or MAAP calculations to determine the success criteria in the PRA. A topical report will be provided on this process.

Mr. Wachowiak concluded by presenting the PRA Level 1 internal events results. The ESBWR PRA shows a core damage frequency of 3×10^{-8} per year. The highest sequence is at 1.6×10^{-8} and the highest cutset is at 5×10^{-10}. He credited the combination of passive and active functions for these results. The top cutsets occur due to common cause failure of the passive systems. Loss of preferred power and loss of feedwater make up the vast majority of the CDF, both of which lead to essentially the same event.

Comments and Observations From the Subcommittee Members

- Dr. Apostolakis asked why the design does not use passive systems only. Mr. Wachowiak replied that the active systems are preferred for event recovery. Though the passive systems are very safe, they are also very expensive to recover from and create more stress on the system components. Dr. Apostolakis then asked why not just have the active systems. Mr. Wachowiak replied that safety-related active systems are more expensive to maintain and have similar reliability, so there are both economic and safety benefits to an active/passive combination.

- Dr. Wallis noted during the discussion of the event trees that many of the systems can partially fail, which isn't a yes/no question. He added that the thermal-hydraulic uncertainties can also make events change branches. Mr. Wachowiak replied that the conservatisms in the analysis should capture these uncertainties. For example, the PRA uses the reactor vessel water level at the top of the active fuel as the definition of core damage.

- Dr. Wallis asked how the PRA was used for design. Dr. Bonaca added that experience from existing BWRs seemed to be the main basis. Mr. Wachowiak provided an example of the reactor water cleanup system, which initially showed a non-negligible contribution to the CDF. The system designers were tasked to reduce that contribution, and added a diverse isolation system to accomplish it. As another example, Mr. Wachowiak described the use of alarms on manual valves to indicate when they are not in the correct position.

- Dr. Apostolakis pointed out several topics he would like to hear more details about during future meetings. These include the common cause failure method (particularly the use of $\beta=0.01$), a discussion of the dominant sequences, and the method for increasing failure rates for longer test intervals.

- Dr. Wallis asked why the frequency of initiating events was based on existing plants. Mr. Wachowiak answered that 1) the data is available, and 2) the primary purpose of the PRA was to assess the performance of the mitigating systems, not just reduce the results through lower initiating event frequencies. Dr. Apostolakis agreed that this was a better approach, to avoid arguments over the use of lower frequencies.

- Dr. Wallis also asked why old reliability values (such as from the Utility Requirements Document) for basic events were used. Mr. Wachowiak replied that their customers requested such, and that there was not a great difference with current data.

- Dr. Apostolakis asked if the PRA has been reviewed. Mr. Wachowiak said that no outside group had reviewed it. He noted that the final PRA which is given to a plant owner will be peer reviewed. Ms. Cubbage confirmed that though a PRA is required at this point in the process, it is used to guide the review and does not require a peer review yet.

- Dr. Apostolakis asked why Mr. Wachowiak reported a CDF of 3×10^{-8} when the mean is 8×10^{-8}. Mr. Wachowiak replied that the lower value comes from using point estimates and is therefore more useful for comparisons with the values from the fire analysis, flood analysis, and other parts of the analysis. He added that the purpose of the value is to show the diversity of the design and to show that the design addresses everything we know about. Dr. Wallis added that, with such a low CDF, intentional acts may be more likely. Mr. Maynard added that the positive actions of humans also need to be credited.

<u>Severe Accident Mitigation</u>

Dr. Theo Theofanous, University of California - Santa Barbara, presented the topic of severe accident treatment in the ESBWR design. Specifically, Dr. Theofanous presented work on containment integrity threats due to severe accident phenomena. Despite the low core damage frequency of the ESBWR, a robust containment design provides defense-in-depth. He started the presentation with the conclusion, that containment failure is physically unreasonable for severe accident scenarios comprising more than 99% of the CDF – the only exception being steam explosions in a very deeply-flooded lower drywell. For those scenarios, they cannot demonstrate containment survival with high confidence.

Dr. Theofanous addressed three severe accident threats: direct containment heating, ex-vessel explosions, and basemat melt penetration. He first discussed the issue of basemat melt penetration, for which a boundary-internal melt arrest and coolability (BiMAC) device is proposed in the ESBWR design. Often referred to as a "core catcher," this device consists of cooling pipes embedded in a sacrificial layer of material on the floor of the drywell under the reactor vessel. If a severe accident caused melted fuel to exit the vessel, it would land on the BiMAC, triggering sensors that flood the BiMAC with water from the gravity-driven cooling system to cool the molten core and prevent core-concrete interactions.

For direct containment heating, Dr. Theofanous described the bounding approach taken to assess the issue. He described the potential failure modes and provided a description of the key features of the containment. Dr. Theofanous discussed the calculations of failure pressures for direct containment heating for several scenarios and noted that additional sensitivity calculations were performed that are not included in the report. Using a conservative approach, Dr. Theofanous stated that containment failure due to direct containment heating is physically unreasonable for the ESBWR design. Though the lower drywell liner may melt through, the design of the liner and pedestal wall should provide isolation from the outside.

Dr. Theofanous then described the assessment of ex-vessel explosions, including examination of pedestal failure and crushing of the BiMAC pipes. Such phenomena cannot be conservatively excluded if a deep, subcooled pool exists in the lower drywell during vessel breach. So the design relies on high equipment reliability to prohibit the formation of such pools. Dr. Theofanous described the use of DYNA3D, a structural analysis code, to calculate the damage to the pedestal during an ex-vessel explosion. DYNA3D was also used to assess the impact of such an explosion on the BiMAC cooling pipes, which showed a high likelihood of survival.

The remainder of Dr. Theofanous's presentation focused on the design of the BiMAC device to prevent basemat melt penetration. Due to the BiMAC, he concludes that containment failure due to basemat melt-through is physically unreasonable. To support this conclusion, Dr. Theofanous described the detailed design of the BiMAC and the parameters included in the calculations. The results show that the heat flux at the edges of the near-edge channels are the most limiting, but still remain acceptable. Dr. Theofanous also described the supporting experiments to assess the critical heat flux under different geometries.

Finally, Dr. Theofanous discussed the need for the BiMAC to be treated as RTNSS. He argued that the function of the BiMAC has been shown in principal based on the existing experimental knowledge, and stated that it will be verified by full-scale testing for the combined operating license stage of the review. He concluded by presenting the different severe accident event trees for low- and high-pressure events.

Comments and Observations From the Subcommittee Members

- Dr. Wallis asked about the probability of failure during an ex-vessel explosion, which is listed as zero for a water height less than a specified level in Table 8.3-4. Mr. Wachowiak stated that it is a PRA calculational tool, which uses zero when the water level is less than that height, but conservatively uses a probability of one for a deeper pool where damage from the ex-vessel explosion cannot be ruled out.

- Dr. Kress asked about the handling of pre-mixing and triggering for steam explosions in the computer codes. Dr. Theofanous stated that UCSB codes were used, and that the worst conditions for these aspects of the event were assumed.

- Dr. Kress questioned whether a uniform distribution of corium was assumed for the BiMAC calculations. Dr. Theofanous answered affirmatively. Dr. Denning asked if that was a good assumption. Dr. Theofanous stated his belief that is was acceptable and noted that others have used the same assumption successfully.

- Dr. Shack asked if similar core spread and core-concrete interactions as with the ABWR would be expected if the BiMAC was not used. Dr. Theofanous answered affirmatively. Dr. Wallis asked what else needs to be done to convince the NRC of the functionality of the BiMAC. Dr. Theofanous stated that the full-scale experiments still remain.

Containment Systems Performance

Mr. Wachowiak continued the presentation, discussing the performance of containment systems to address the remaining severe accident mitigation issues. He stated that containment bypass can only occur if large penetrations are open to the environment. In the ESBWR design, all containment penetrations were identified as either normally closed during operation, connected to a closed system inside containment, connected to a closed system outside containment, or already addressed in the Level 1 analysis as a break outside containment. Given these qualities, Mr. Wachowiak claimed that containment bypass is not credible for the ESBWR, though the design does not yet include much of the smaller piping penetrations.

For overpressure protection, Mr. Wachowiak identified the passive containment cooling system (PCCS), fuel & auxiliary pool cooling system (FAPCS), and manual venting functions. The PCCS system is designed to operate passively for the first 24 hours of an event by condensing steam in the drywell and returning it to containment. The FAPCS acts as an active backup to the PCCS. The only potential issue with the PCCS is the buildup of non-condensable gases that can reduce the effectiveness of the system. To combat this, the design provides a vent line that operates so long as the vacuum breakers are seated. Mr. Wachowiak then described the design and operation of the vacuum breakers to assure PCCS operation. After 24 hours, water makeup is needed to maintain PCCS operability. Mr. Wachowiak showed where the PCCS is called upon in the PRA containment event trees and stated that failure of the PCCS is extremely unlikely in 99% of core damage sequences. Overpressure can occur after 24 hours for some high-pressure sequences, but can be somewhat mitigating by a filtered venting of the containment.

Comments and Observations From the Subcommittee Members

- Dr. Wallis asked if debris could block the PCCS drain lines or non-condensable line. Mr. Wachowiak answered that such debris was considered in the design, the system has guards to prevent debris from entering, and testing has been performed to look at particulates.

- Dr. Denning asked how the PCCS is tested. Mr. Wachowiak stated that the system is inspected during outages.

- Dr. Denning also asked what makes the 1% of core damage sequences vulnerable. Mr. Wachowiak identified those as high-pressure sequences without DC power, which require operator action to add water in a potentially high-radiation environment.

- Dr. Denning asked if any credit is taken for the filter during venting. Mr. Wachowiak answered that no credit is taken for its reliability, but credit is considered during calculation of the source term.

Offsite Consequence Analysis

Mr. Sid Bhatt began the second day of the meeting with a presentation on the offsite consequence analysis. He stated the three goals of the analysis: individual risk of prompt fatality below 3.9×10^{-7}, a "societal risk" of cancer fatality below 1.7×10^{-6}, and a radiation dose goal below 10^{-6} for 0.25 Sv at 0.5 mile. The first two goals come from the quantitative health objectives, the third from the EPRI Utility Requirements Document (URD). Mr. Bhatt described the overall assessment method using MAAP calculations for the source term and MAACS to calculate the offsite consequences. Because the ESBWR is in the design stage and is not sited yet, the analysis uses meteorology from the URD and the most dense population from the Sandia Siting Study. No evacuation or relocation credit is given, and conservative assumptions are made for wake effects, release height, and plume heat content. Mr. Bhatt presented the results of the calculations, which easily meet the goals at both 24 hours and 72 hours after the onset of core damage. The prompt fatality risk is on the order of 4×10^{-11}, the cancer risk is 6×10^{-12}, and the radiation dose is 3×10^{-9}.

Comments and Observations From the Subcommittee Members

- Dr. Kress pointed out that what is labeled as "societal risk" in the presentation is just another form of individual risk (latent cancer).

- Dr. Kress asked about the effects of a 0.25 Sv dose. Dr. Denning pointed out that health effects begin to appear at that level.

- Dr. Apostolakis asked if an uncertainty analysis was performed. Mr. Bhatt answered that it was not. Dr. Apostolakis then asked how high the results could be. Mr. Wachowiak answered that the results are bounding, since the Level 2 analysis is bounding and upper limits were used for the source term.

External Events Risk Management

Mr. Wachowiak returned to describe the ESBWR external events risk calculations and results. He began with a description of the probabilistic fire analysis, which used the FIVE methodology to identify fire compartments, define fire ignition frequencies, and perform quantitative screening of the fire risk. The analysis shows that the risk of fire in each of the area groups is lower than the risk of core damage due to internal events. Mr. Wachowiak then provided additional detail of the fire analysis. It included fire scenarios in the reactor building, control building, fuel building, turbine building, electrical building, and service water building for both full power and shutdown operations. To compensate for a lack of detail at this stage of the design, the analysis made bounding assumptions on fire growth within a building to all equipment in the division, no credit for fire protection, and worst-case spurious actuation. The fire results show that all scenarios but one have a CDF less than 3×10^{-10}. The one scenario, in the turbine building, has a CDF of 1×10^{-8} due to a high initiating frequency and treatment of the entire turbine building as one area, which creates a loss of feedwater scenario. GE is still working on how to address this scenario. Fire results during shutdown are still under development.

Mr. Wachowiak then described the probabilistic flooding analysis, which addressed floods in the same buildings addressed during the fire analysis. As a conservative assumption, the historical flooding frequencies were applied in full to each building rather than apportioning the frequency among the buildings. Mr. Wachowiak briefly described the flooding sources and scenarios in each building, then presented the results of the analysis, which shows flooding is not a dominant contributor to the overall plant CDF. Key features that contribute to the flooding results include the layout of the safety design features, redundancy and physical separation of safety equipment, alternate safe shutdown features in other buildings, watertight doors on the control and reactor buildings, floor drains in the reactor and control buildings, and an automatic pump trip and valve closure if high water level occurs in the condenser pit.

For risk due to high winds (tornados), Mr. Wachowiak described the approach as treating the event as a loss of preferred power without recovery for 24 hours, with an assumed failure of the condensate storage tank due to wind-driven missiles. Because the initiating event frequency is much lower than a random loss of preferred power, the risk due to this scenario is very small, approximately 10^{-12}.

Mr. Wachowiak concluded this session by describing the analysis of seismic risk for the ESBWR. A seismic margins analysis was performed to address the capability of the safety systems to survive a seismic event. The analysis determined the necessary fragility for all safety systems, which will need confirmation once a plant is built. The analysis assigns these fragility values to each branch in the event trees to determine the capability of the plant. The results indicate that all sequences have a capability of at least two times the safe shutdown earthquake. Therefore, Mr. Wachowiak stated that it is unlikely that seismic events will be a vulnerability for the ESBWR. Mr. Wachowiak stated that he could not predict what the quantitative results of a seismic PRA would be.

<u>Comments and Observations From the Subcommittee Members</u>

- Dr. Wallis asked why the fire risk was lower relative to operating plants. On a similar note, Dr. Apostolakis asked what was meant by “insignificant” when the CDF is already 10^{-8}. Mr. Wachowiak responded that the need for separation due to fire concerns is much better understood now. In addition, the optic fiber-based I&C system is not subject to the same kinds of failure modes.

- Dr. Apostolakis asked if fire concerns would not be included at the COL stage due to the low risk. Mr. Wachowiak answered that the fire-related characteristics would still need to be confirmed at the COL stage. Ms. Cubbage added that such issues would likely be included as an ITACC issue.

- Dr. Wallis asked whether the assessment of spurious actuations due to fires assumed the use of copper wires. Mr. Wachowiak replied that in Revision 0, they did so. However, they now assume the bounding spurious actuation despite the use of fiber optic cabling. Dr. Denning followed up by asking if only one spurious actuation was assumed. Mr. Wachowiak confirmed that, but noted that it was bounding.

- Dr. Denning asked if the active systems also had fire separation. Mr. Wachowiak answered that they do, to the degree possible.

- Dr. Bonaca noted that since the agency cannot impose more than the current regulations, the results could change upward and still be acceptable. Ms. Cubbage noted that if changes occur, the agency would still need to confirm compliance with the regulations.

- Dr. Denning asked what effects a spurious actuation of the squib valves that drain the gravity driven cooling system onto the BiMAC would have. Mr. Wachowiak agreed that was a good question and stated they would need to address that.

- Dr. Denning asked whether fire barriers are considered perfect or whether they are treated with a probability of failure. Mr. Wachowiak stated that in Revision 0, they were perfect, but in Revision 1, they postulate the failure of one barrier using EPRI guidance, but still use the conservative assumption that all equipment in the affected division fails.

- Dr. Denning asked if other design principles, aside from physical separation, were adopted due to the PRA. Mr. Wachowiak provided an example of the control building, which is mostly underground. The fire code requires hose stations, which pose a potential flooding risk and increase the probability of a flood in the control building. To alleviate this, they redesigned the system to keep the fire main outside the building and lower the probability of flood to a more acceptable level.

- Dr. Apostolakis noted the need to revisit the flooding analysis and results in more detail at a future meeting.

- Dr. Apostolakis asked why it was important to GE to make the external event risk insignificant. Mr. Wachowiak stated two reasons. First, since the external event analyses are bounding, they wanted to be well below the internal events risk. Second, this provides for cleaner applications if external events can be neglected.

- Dr. Denning stated that he believes that seismic risk will dominate, since the internal events CDF is so low. Dr. Wallis agreed, since the current work is only a seismic margins analysis. Dr. Apostolakis noted that a source of common cause failures is needed in this design to cause concern, such as what might occur in a large fire or seismic event. Dr. Denning noted that fire vulnerabilities can be designed out, while seismic is different. Mr. Wachowiak stated that seismic issues are not dismissed, just that they are not a vulnerability.

Shutdown Risk Management

Mr. Wachowiak briefly discussed the initial results and status of the ESBWR shutdown risk management program. It includes the assessment of internal and external events and seismic margins for operating modes 5 (cold shutdown) and 6 (refueling). Mr. Wachowiak stated that the shutdown analysis was performed at the same level of detail as the power operation PRA. He then discussed the potential initiating events during shutdown and the important maintenance activities occurring during shutdown that affect risk. He also described the types of recovery actions that operators can perform during shutdown events, and noted that these events progress much slower, therefore allowing more time for recovery. Specifically, Mr. Wachowiak discussed the recovery of shutdown cooling, offsite power, and service water as key recovery events during shutdown conditions.

The results from the shutdown risk analysis indicate a LOCA as the primary contributor. Mr. Wachowiak used a diagram of the reactor building to illustrate the water capacity of containment during shutdown. With the lower hatches closed, the plant can flood well above the reactor core if necessary during a shutdown accident. Insights from this analysis are being factored into the final design of the plant. Mr. Wachowiak also noted that the risk analysis highlighted the importance of controlling fire barriers during shutdown. The fire and flood models for shutdown are still under development.

Comments and Observations From the Subcommittee Members

- Dr. Wallis asked if a shutdown LOCA would prevent the lower hatches from closing. Mr. Wachowiak stated that the water level would not reach the level of the hatches for 1½ - 3 hours. The designers are also incorporating the need to not route pipes near the hatches to address the same question.

- Dr. Armijo asked if the shutdown LOCA scenario was unique to the ESBWR. Mr. Wachowiak answered affirmatively, since the suppression pools are at a higher elevation in the reactor building than with existing BWRs.

ESBWR Risk Management Insights

Mr. Wachowiak concluded GE's portion of the meeting by summarizing the insights gained from the ESBWR PRA. He stated that the PRA results meet the desired goals, use an appropriate scope, enhance the defense-in-depth of the plant, have been used as a valuable design tool, and will continue to evolve as the design leads to plant operation. The overall results he discussed are attributable to the effect of the robust design on the low CDF and LRF.

Requests for Additional Information

Ms. Cubbage then discussed the requests for additional information the staff developed in response to GE's Design Document and PRA submission. She was joined in the presentation by NRR review team members Bob Palla, Marie Pohida, and Nick Saltos. Topics discussed include peer review results for the ROAAM methodology used for severe accident phenomena, equipment survivability assessments, isolation condenser makeup, Severe Accident Mitigation Design Alternatives, overall containment performance for all accident classes, ex-vessel steam explosions, and the BiMAC system. The staff also requested an expanded uncertainty and importance assessment regarding key containment-related features, including containment isolation provisions. The staff requested a systematic assessment of the impact of thermal-hydraulic uncertainty on the PRA models and results and more documentation of the process for selecting RTNSS systems. Additional topics of RAIs included submission of additional cutsets, identification of design requirements based on PRA insights, references for component reliability, detailed evaluations of important human actions, details of the fire risk analysis, assessment of fires and floods during shutdown, and discussion of large release frequency during shutdown. Additional issues were identified during meetings, including assessment of potential RCS draindown paths through the RWCU/SDC system, the impact on Level 2 results if BiMAC is not credited, the effect of molten core impingement on the lower drywell hatch, and modeling of the digital I&C system in the PRA.

Comments and Observations From the Subcommittee Members

- Dr. Apostolakis asked for clarification as to which uncertainties were meant during the discussion of thermal hydraulic uncertainties. Mr. Saltos responded that they included uncertainties in parameters, physical conditions, and numerical methods. Dr. Denning suggested that the question also addresses the issue of phenomenological uncertainties associated with the probability of system failure, and that this is an important issue that the Committee should hear more about. Mr. Saltos mentioned that GE is preparing a topical report on the issue.

- Dr. Apostolakis asked what the staff expected in terms of modeling digital I&C systems in the PRA. Mr. Saltos responded that the expected modeling would be at a high, bounding level. The vendor should use basic events in the PRA where knowledge is available to support the analysis, and use conservative assumptions in areas where sufficient knowledge does not exist to support the analysis.

Severe Accident Analysis

Ms. Cubbage then introduced Mr. Mohsen Khatib-Rahbar, Energy Research Inc. (ERI), a contractor for the Office of Nuclear Regulatory Research, to provide a presentation on the staff's confirmatory analysis for severe accidents in the ESBWR. After outlining his presentation, he reviewed the objectives of the research – to support the design certification review of severe accident risk through independent assessment of severe accident response, confirmatory assessment of radiological release estimates, development of uncertainties for analysis of selected severe accident issues, and confirmatory analysis of selected severe accident issues.

Mr. Khatib-Rahbar described the model development performed for this project in MELCOR, the agency's severe accident analysis code. His team developed MELCOR input decks, subjected them to independent quality assurance and review, adjusted to input decks back to a previous version of MELCOR due to code performance issues, and performed initial baseline calculations while working to resolve the performance issues. The MELCOR models included containment spray and containment venting systems, and the ability to refill the passive containment cooling and isolation condenser pools. The model did not explicitly model the BiMAC system.

Mr. Khatib-Rahbar then compared ERI's results to GE's results for steady-state conditions in order to confirm the validity of the models. He then described the analysis of a loss-of-feedwater event taken from the ESBWR PRA. The calculation accounted for the loss of both short- and long-term coolant injection, automatic depressurization actuation at the appropriate time, loss of heat removal by the isolation condensers, successful makeup to the passive containment cooling and isolation condenser pools, and operation of the GDCS deluge system. They considered two cases to assess the performance of the containment – one with a "perfect" BiMAC function (i.e., no core-concrete interaction) and one without the BiMAC function. Mr. Khatib-Rahbar discussed the results of these calculations in comparison with the GE results to show general agreement.

Mr. Khatib-Rahbar finished his presentation by discussing the rationale being used to select additional scenarios for analysis. The staff and contractors plan to assess several risk-dominant, frequency-dominant, and consequence-dominant scenarios. His team is awaiting additional data from GE before completing final calculations.

Comments and Observations From the Subcommittee Members

- Dr. Apostolakis asked if the calculations by ERI that assumed no BiMAC function met the needs expressed by Bob Palla in a request for information. Mr. Palla replied that it does not. The ERI calculation addressed only one scenario, while Mr. Palla wanted information on the sensitivity of the overall results without the BiMAC.

Closing Discussions

Closing Comments and Observations From the Subcommittee Members

- Dr. Denning asked if Dr. Apostolakis assumed that no letter would be written at this time. Dr. Apostolakis replied that the Committee could write an interim letter if desired, but the decision was up to the Committee.

- Dr. Denning stated that everything he had seen so far was quite constructive. He does not see a reason for a letter at this time.

- Dr. Apostolakis also stated that he was not inclined to write an interim letter.

- Dr. Bonaca agreed that he didn't see anything warranting a letter.

SUBCOMMITTEE DECISIONS AND ACTIONS

The subcommittee raised several issues to be discussed at future meetings, and decided that no interim letter was necessary at this time.

BACKGROUND MATERIALS PROVIDED TO THE SUBCOMMITTEE PRIOR TO THIS MEETING

Documents	
0.	ESBWR Probabilistic Risk Assessment, Revision 0, NEDC-33201P.
1.	Letter from L. Rossbach, Project Manager, NRR, to D. Hinds, ESBWR Manager, GE, “Request for Additional Information Letter No. 3 for the ESBWR Design Certification Application,” 8 Dec 2005.
2.	Letter from D. Hinds, ESBWR Manager, GE, to USNRC, “Response to NRC Request for Additional Information Letter No. 3 for the ESBWR Design Certification Application - PRA - RAI Number 19.0.0-1,” MFN 05-165, 19 Dec 2005.
3.	Letter from D. Hinds, ESBWR Manager, GE, to USNRC, “Response to NRC Request for Additional Information Letter No. 3 Related to ESBWR Design Certification Application - Chapter 19 - PRA & Severe Accident,” MFN 05-169, 29 Dec 2005.

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Note: Additional details of this meeting can be obtained from a transcript of this meeting available for downloading or viewing on the Internet at http://www.nrc.gov/ACRSACNW or can be purchased from Neal R. Gross and Co., Inc., (Court Reporters and Transcribers) 1323 Rhode Island Avenue, NW., Washington, DC 20005 (202) 234-4433.