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

February 14, 2006

MEMORANDUM TO: ACRS Members

FROM: Eric A. Thornsbury, ACRS Senior Staff Engineer

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEES ON HUMAN FACTORS AND RELIABILITY & PROBABILISTIC RISK ASSESSMENT, DECEMBER 15-16, 2005 - ROCKVILLE, MARYLAND

The minutes of the subject meeting, issued January 23, 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
J. Lamb

GT190602

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

January 23, 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

SUBJECT: WORKING COPY OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEES ON HUMAN FACTORS AND RELIABILITY & PROBABILISTIC RISK ASSESSMENT, DECEMBER 15-16, 2005 - 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
A. Thadani
M. Scott
S. Duraiswamy
M. Snodderly

UNITED STATES
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WASHINGTON, DC 20555 - 0001

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

FROM: Mario V. Bonaca, Chairman
Human Factors Subcommittee

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEES ON HUMAN FACTORS AND RELIABILITY & PROBABILISTIC RISK ASSESSMENT, DECEMBER 15-16, 2005 - ROCKVILLE, MARYLAND

I do hereby certify that, to the best of my knowledge and belief, the minutes of the subject meeting on December 15-16, 2005, are an accurate record of the proceedings for that meeting.

Mario V. Bonaca 2/9/06

Mario V. Bonaca
Subcommittee Chairman

Date

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
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 SUBCOMMITTEES ON HUMAN FACTORS AND RELIABILITY & PROBABILISTIC RISK ASSESSMENT, DECEMBER 15-16, 2005 - ROCKVILLE, MARYLAND

I do hereby certify that, to the best of my knowledge and belief, the minutes of the subject meeting on December 15-16, 2005, are an accurate record of the proceedings for that meeting.

George E. Apostolakis
Subcommittee Chairman

2/10/06
Date

Issued: 1/23/2006
Certified: 2/10/2006

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE ACRS SUBCOMMITTEES ON
HUMAN FACTORS AND
RELIABILITY & PROBABILISTIC RISK ASSESSMENT
MEETING MINUTES - DECEMBER 15-16, 2005
ROCKVILLE, MARYLAND

INTRODUCTION

The ACRS Subcommittees on Human Factors and Reliability & Probabilistic Risk Assessment held a meeting on December 15-16, 2005, in Room T-2B3, 11545 Rockville Pike, Rockville, MD. The purpose of this meeting was to review the status of the agency's current research on Human Reliability Analysis. 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 December 15, 2005, recessed at 6:20 p.m., reconvened at 8:30 a.m. on December 16, 2005, and adjourned at 10:45 a.m..

ATTENDEES

ACRS Members

G. Apostolakis, Subcommittee Chairman
M. Bonaca, Subcommittee Chairman
T. Kress, Member
E. Thornsbury, Designated Federal Official

Principal NRC Speakers

J. Yerokun, RES
A. Kolaczkowski, SAIC
S. Cooper, RES
A. Bye, HRP
B. Hallbert, INL
E. Lois, RES
J. Forester, SNL
D. Gertman, INL
P. Braarud, HRP

Other Principal Speakers

F. Rahn, EPRI
J. Julius, Scientech
Z. Elawar, PVNGS
A. Mosleh, UMD

Other members of the 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 review the status of the agency's current research on Human Reliability Analysis (HRA). 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 November 28, 2005. Dr. Apostolakis acknowledged that the Committee had received no written comments or requests for time to make oral statements.

DISCUSSION OF AGENDA ITEMS

EPRI HRA Calculator

Dr. Frank Rahn, EPRI, began the presentations. He first introduced his colleagues that would be presenting other portions of the discussion, then provided a brief discussion of the organization of the EPRI HRA Calculator Project. After reviewing key HRA-related EPRI research over the past twenty years, he passed the presentation to Dr. Zouhair Elawar.

Dr. Elawar, Palo Verde Nuclear Generating Station, provided a briefing on the background of the EPRI HRA Calculator. He discussed the analyst factors that were a significant source of variation in industry HRAs. EPRI designed the HRA Calculator to facilitate a standardized approach to human reliability analysis while meeting utilities' needs for all current and foreseeable PRA and regulatory needs. Dr. Elawar described the main objective of the calculator to meet the HRA criteria in the ASME PRA standard. He also reviewed the members of the EPRI HRA user's group and discussed their mission. Dr. Elawar also stated that the uncertainty seen in this approach to HRA is comparable to that of other PRA aspects. He finished by describing uses of the method in HRA updates, configuration risk management, the SDP process, operator training, and other licensing issues.

Dr. Rahn returned to the microphone to lead the next discussion on the status of the HRA Calculator and some of its applications. He reviewed the development of the tool to provide immediate use by the members, defensible and reproducible results, and easy-to-use software. The development also includes guidelines and training to support consistent application and direct mapping to the ASME PRA standard. Dr. Rahn discussed the work the HRA user's group does with universities, how the group provides a focal point for feedback to NRC, and the benefits the international members of the user's group provide. For example, the project is following the development of the French method MERMOS.

Dr. Rahn concluded his portion of the presentation by discussing the HRA models contained within the HRA calculator. For pre-initiator (latent) analysis, the user has a choice of the THERP model from NUREG/CR-1278 or the ASEP model from NUREG/CR-4772. For post-initiator (dynamic) analysis, the user can choose from the cause-based decision tree (CBDTM), HCR/ORE, the Annunciator Response model, and/or THERP.

Dr. Jeff Julius, Scientech, provided the subcommittees with a technical description and demonstration of the EPRI HRA Calculator. He described how the technical approach follows

the general process of identification, screening, qualitative characterization, quantification, and dependency evaluation. The method also requires the input of performance shaping factors. Dr. Julius then provided an overview demonstration of the software's functions and features, including the pre-initiator module, the post-initiator module, and the dependency analysis module. He also described how the software interfaces with other PRA programs and showed how it produces documentation for the users.

Dr. Rahn and Dr. Elawar rejoined Dr. Julius to provide a summary and conclusions to the presentation.

Comments and Observations From the Subcommittee Members

- Dr. Apostolakis asked if they had tested the calculator with different users (i.e., use two groups to analyze the same application). Dr. Elawar stated that complete agreement among users was not possible. Dr. Rahn added that the main testing approach is through the peer review process, where they are finding good consistency among groups. Dr. Apostolakis raised the issue of the European HRA benchmark study published in 1989 and suggested that the HRA community needs to address the results.

- Dr. Bonaca asked if the method has had any validation through the use of simulators. Dr. Elawar answered that they do use simulator training and other sources of simulator data.

- Dr. Apostolakis asked Dr. Elawar which parts of the EPRI HRA Calculator web site he can see. Dr. Elawar promised to send a sample HRA to Dr. Apostolakis for his information.

- Dr. Bonaca asked how the models were chosen to include in the calculator. Dr. Rahn replied that they used a pragmatic approach that included all the models being in use by industry at the time.

- Dr. Apostolakis asked Dr. Julius if they had questioned any of the assumptions of the models adopted in the calculator. Dr. Julius said no, but anything is subject to later questioning.

- Dr. Apostolakis asked if the NRC staff had reviewed the HRA Calculator. Dr. Rahn answered that it is available for review. Dr. Erasmia Lois, RES, added that the staff did review the calculator as part of its review of HRA methods.

- At the conclusion of the session, Dr. Apostolakis commented that consistency is important, the tool appears good, and suggested an exercise to compare results from different groups. Dr. Bonaca stated that the level of detail in the tool and the training that accompanies it impressed him. Dr. Kress stated that it has a good framework, thinks an exercise would be worthwhile, and would like to see more of the database that supports the tool.

Overview of Human Reliability Research Activities

Mr. Jimi Yerokun, Section Chief in the Office of Nuclear Regulatory Research, began the staff's presentation by reviewing the objectives of the briefing: to provide an update on NRC's human reliability analysis research programs and to address current interests of the ACRS. The staff hopes to obtain input from the Members to inform their planning of HRA activities. He then presented the goals and objectives of the research program and described the major focus of the research to support NRC's action plan on stabilizing the PRA quality expectations and requirements. Mr. Yerokun provided an overview of the upcoming briefings and presented a graphical description of how the human reliability program fits into the larger picture.

Evaluation of HRA Methods

Dr. Erasmia Lois introduced the next topic on the Evaluation of Human Reliability Analysis Methods Against HRA Good Practices. As part of the "PRA Action Plan for Stabilizing PRA Expectations and Requirements," the staff is developing guidance for performing and reviewing HRA. The first phase of the work created the HRA Good Practices document, NUREG-1792. The second phase is the evaluation of various HRA methods against those good practices, the topic of this presentation.

Dr. Lois described the review team's approach and the expert meeting held to discuss the initial evaluation results. She noted that outside experts performed the review of current NRC methods to provide an independent perspective. She briefly listed the methods reviewed, all of which are domestic thus far. Dr. Lois then summarized the overall results of the evaluation in terms of general strengths and weaknesses. She also noted the evolution in thinking on quantifying human failure that is evident in the range of methods. The overall perspective of the review views the methods as a "tool box" that provides a range of methods for different types of analyses. Consequently, she noted the importance of using the right method for the right application, and using it in the way the designers intended.

Dr. Lois then introduced Dr. Alan Kolaczkowski and Dr. John Forester to describe the evaluations of specific methods. Dr. Kolaczkowski began with a discussion of the Technique for Human Error Rate Prediction (THERP), from NUREG/CR-1278. He reviewed the scope of the method, the underlying model and data, and the quantification approach. He noted that the quantitative factors rely on the expert judgement of the authors. Dr. Kolaczkowski finished by describing the strengths and weaknesses of THERP. Strengths include good qualitative insights, wide application and use, a broad range of performance shaping factors (PSFs), and explicit handling of diagnosis and implementation failures. Weaknesses include resource-intensiveness, misapplication, one-size-fits-all diagnosis, and actually addressing only a relatively small set of PSFs in the quantification.

Dr. Kolaczkowski continued the discussion with a description of the Accident Sequence Evaluation Procedure (ASEP) method. He described the scope of the method and its underlying model, discussing its approach to pre- and post-initiators. The quantitative values in ASEP use the same basis as THERP, but are more conservative. Like with THERP, he described the strengths and weaknesses. Strengths include ease of use, simplicity, thorough analysis of pre-initiators, explicit handling of diagnosis and implementation failures, and commonly accepted results. Weaknesses include likely misjudgements by non-experts due to

lack of guidance, lack of ability to handle extreme or unique PSFs, and similar data limitations as THERP.

Dr. Forester continued the briefing by discussing the scope and underlying model for the Human Cognitive Reliability (HCR) / Operator Reliability Experiments (ORE) method, developed by EPRI. The strengths of HCR/ORE include strong empirical data and a straightforward and traceable derivation of human error probabilities. Weaknesses include the need for simulator runs to create the empirical evidence, a lack of guidance for obtaining expert judgements for crew response times, questionable generalization of plant-specific simulations, and lack of a systematic approach to identify human response vulnerabilities.

Dr. Forester also presented the evaluation of the Cause-Based Decision Tree (CBDT) method, also developed by EPRI. He described it as a quantification technique for estimating non-response probability of post-initiator human actions. Strengths of the method include a required evaluation of potential causes of errors, ease of use, flexible selection and application of PSFs, and suggestions for other relevant factors not covered by the decision trees. Weaknesses include a lack of guidance for time-limited conditions, lack of guidance to support the flexible selection and application of PSFs, an assumption of independence among the factors in the decision trees, the use of THERP data, and potential misapplication of the self recovery feature.

Dr. Kolaczkowski presented the staff's review of the EPRI HRA Calculator, noting that it is a software tool and not a model. It automates the use of a number of other methods. Strengths of the calculator include improved consistency, good traceability and documentation, and flexibility. Weaknesses include potential misuse without training, lack of guidance for which method to use, lack of guidance on using its flexibility, and non-use of some PSFs during quantification. Dr. Kolaczkowski also discussed the sigma decision tree option contained in the HRA Calculator.

Dr. Kolaczkowski continued the presentations with a discussion of the SPAR-H method included in the Standardized Plant Analysis Risk (SPAR) models. It is a quantification technique for diagnosis and action human failure events to provide reasonable estimates for regulatory uses. Strengths of this method include simplicity of use, good coverage of many situations, detailed discussion of PSF interactions, explicit handling of diagnosis and action failures, and some validation of the values by comparison to other methods. Weaknesses include misuse by non-experts, independent treatment of PSFs, insufficient guidance for PSFs, inadequate resolution for more detailed analysis, and lack of explicit guidance for addressing a wider range of PSFs if needed.

Dr. Forester discussed the evaluation of A Technique for Human Event Analysis (ATHEANA), documented in NUREG-1624. This method strives to address a wide range of performance conditions and failure modes, and is based on a four-stage behavioral sciences view. Strengths of ATHEANA include thoroughness, consideration of a range of different conditions, direct uncertainty evaluation, and consideration of errors of commission. Weaknesses include difficulty in reproducing results, complexity, resource and time intensiveness, insufficient guidance for addressing the broad range of factors, and insufficient guidance for producing human error probabilities.

After skipping over the discussions of the Success Likelihood Index Methodology (SLIM) Multi-Attribute Utility Decomposition (MAUD) method, the Failure Likelihood Index Methodology

(FLIM), and a revised Systematic Human Action Reliability Procedure (SHARP1), Dr. Lois summarized this discussion by reviewing the next steps for the project. The staff is considering development of a regulatory guide and/or SRP addressing methods for regulatory use. They are also planning to expand their review to international methods. In general, the HRA community could achieve continued improvement of the methods through common frameworks, improved technical bases, improved quantification capabilities, and an expanded knowledge base.

Comments and Observations From the Subcommittee Members

- Dr. Apostolakis asked why the staff doesn't recommend against the use of some methods. Dr. Lois noted that they discussed this question during the expert meetings, where they concluded that some weaker methods may still be useful for some conservative analyses. Dr. Apostolakis suggested that the NRC send a clear message that they will not accept some methods.

- Dr. Apostolakis commented during the discussion on the staff's review of the EPRI HRA Calculator that a key question is how to find the optimum balance between standardization and flexibility. The staff agreed.

- Dr. Apostolakis posed a question to help guide the research program: What should an NRC staffer look like in 10 years? Dr. Kolaczkowski provided his view that such a staffer should have a solid background in behavioral sciences.

ATHEANA & SPAR

Dr. Susan Cooper began the next session that summarized the current status of ATHEANA and SPAR-H, the NRC's two current HRA methods. She first reviewed the different objectives and uses of the methods, then presented the details of ATHEANA.

Dr. Cooper began by describing ATHEANA as a perspective on why serious accidents occur. It provides an approach for human reliability analysis both retrospectively and prospectively. It includes a process for both qualitative and quantitative HRA, search schemes for human failure events and error forcing contexts, and a quantification approach including uncertainty. She reviewed the reasons for the development of ATHEANA, to improve the state-of-the-art by incorporating advances in behavioral sciences to more realistically represent human behavior in accidents and near-accidents.

After reviewing the improvements ATHEANA contains, Dr. Cooper discussed applications in which the staff has used ATHEANA, including pressurized thermal shock, a joint NRC/EPRI fire analysis, steam generator tube rupture, and an NMSS spent fuel handling project. Dr. Cooper finished her portion of the presentation by discussing the future plans for ATHEANA. The principal focus of the project is now technology transfer through development of a user's guide and training workshops. The staff is also identifying additional applications for ATHEANA, possibly including analysis of advanced reactor designs, retrospective analysis of operating events, and Yucca Mountain.

Dr. David Gertman, Idaho National Laboratory, provided the staff's discussion on SPAR-H. He described the rationale for development of the program, in which the NRC asked INL to develop

a method for simple, realistic analysis of human error for the SPAR program. Many second generation HRA activities, including international research and ATHEANA, informed the development of SPAR-H. Dr. Gertman described the assumptions inherent in the method that make it applicable to most situations. To complete the presentation, he discussed the contents of the SPAR-H report (NUREG/CR-6883), which includes updates to the PSF definitions, incorporates both positive and negative effects of PSFs, provides worksheet examples, offers an improved uncertainty approach, provides more technical basis, and extends the method to low-power & shutdown conditions.

Comments and Observations From the Subcommittee Members

- Dr. Apostolakis asked if ATHEANA's context-driven approach is useful for safety culture. Dr. Cooper answered that the RES HRA group has not yet been involved in the safety culture work, though the human factors staff has. Mr. Yerokun added that it may not be appropriate yet for HRA involvement, since the safety culture work is still in the development stages.

- Dr. Bonaca asked if the staff was planning to maintain both HRA methods. Dr. Gertman replied that he believes it to be a good idea, since the two methods represent different tools for different applications.

- Dr. Apostolakis commented that it would be useful to see an example of disagreements with industry on human reliability analysis during the significance determination process. Mr. Cheok said the staff would follow up on this during a spring briefing on SPAR-H.

- Dr. Apostolakis commented during the SPAR-H presentation that the staff should note some PSFs as only useful for retrospective analysis. He also asked about the basis for the PSFs and if a mapping exists for the PSF seen in the Halden report (high information load). Dr. Apostolakis suggested use of a deliberative approach for multiple PSFs rather than a formula.

Halden Experiments

Dr. Andreas Bye, Halden Reactor Project, provided the briefing on the Halden experiments and data collection activities supporting HRA. Mr. Bye first discussed the role of data in HRA and how data from simulators such as Halden informs HRA practitioners, method development, and quantification. He also discussed how the staff will use data from the Halden project to populate the HERA database.

Mr. Per Øivind Braarud then described the task complexity experiment for the Subcommittees. This simulation examined three task complexity factors (time pressure, information load, and masking) to see how they affect human performance. Mr. Braarud described the participants in the simulator study – seven three-operator crews from the simulated plant or its sister plant. The simulator is based on s Swedish BWR plant. He described the simulator setup, the operation procedures used during the study, and the training the crews receive on the simulator. Mr. Braarud continued by describing the scenarios used for the study and how they implement the complexity factors in the scenarios. He also described the experimental design for the experiments in terms of balance in the scenarios.

He continued the presentation and discussed the results of each complexity factor. He first described the masking factor experiments, showing both the main tasks and the additional masking tasks the operators needed to perform. The results of this series of experiments show that the response time for the main task relates to the difficulty of the additional task. In particular, if the additional task has either unclear cause and effect relationships, a potential for misdiagnosis, or a high cost of non-resolution, it can have a complicating effect on the main task.

For the time pressure and information load factors, Mr. Braarud again described the experiments, including the main tasks and additional tasks. Variants for this experiment included performance of only the main tasks, the main tasks with time pressure, the main tasks with information load, and the main tasks with both time pressure and information load. He presented the results of the experiment in terms of time to completion of the main task. The analyses indicate that the division of work and resource management present a vulnerability for some crews.

Mr. Braarud and Dr. Bye also discussed the relevance of their work to second generation HRA methods and ATHEANA. Halden provides qualitative insights on context and crew characteristics. It also shows the need to consider additional tasks that could distract the crew and may indicate the need for HRA methods to search for such tasks. They concluded by discussing the next steps for the project: document the method, perform additional experiments in 2006, and examine issues related to the generalization of their results.

Comments and Observations From the Subcommittee Members

- Dr. Apostolakis asked how the data from the simulator study is applicable to American crews. Mr. Bye answered that they use very controlled studies, crew characteristics are similar around the world, and they use standard emergency operating procedures. He added that they would like to work with American crews in the future.

- Dr. Apostolakis suggested experiments to examine whether PSFs are independent.

HERA Data & Bayesian Methods

Dr. Lois introduced the first topic of the second day of the meeting. She also noted that Dr. Ali Mosleh is representing himself at the meeting due to his interest in the topic. He is not under contract to NRC or acting for them in any capacity at this meeting. She then turned the presentation over to Dr. Bruce Hallbert to begin the formal presentation.

Dr. Hallbert, Idaho National Laboratory, first provided an overview of the morning's presentations. The goal was to update the Members of the status of efforts related to data production and system development for the Human Event Repository and Analysis (HERA) database. After reviewing some background information, Dr. Hallbert described the objective of the project as the systematic collection of information about human performance in PRA-relevant settings. Their approach involves identification of information sources, development of a process for extracting information, development of a repository for the information, and development of quantification approaches to allow use of the information.

Dr. Hallbert continued by describing the structure for the HERA database. Section I contains plant and event overview information. Dr. Hallbert described the details for the initiating event, latent condition, and active condition entries. He then described how they record the subevents in codes in Section II of the database. He continued by describing how Section III contains dependency information about the human subevents. Dr. Hallbert also provided an example of a HERA subevent profile based on an actual event. Dr. Hallbert concluded this portion of the presentation by describing the status of the project, which has captured information from 45 licensee event reports (LERs) in approximately 700 data records.

Dr. Hallbert then introduced the remainder of the presentations, which summarize a workshop on use of Bayesian methods for HRA. Dr. Ali Mosleh, University of Maryland, began the first of these presentations.

Dr. Mosleh presented his work on Bayesian Methods and HRA. He described how Bayesian inference works and how HRA applies the variables. He framed the presentation with questions about the uncertainties in operator response and the probability of that response. He then discussed different models used for the probability of a response, and a possible explanation for why the actions have a probability.

Dr. Mosleh then discussed three possible areas of application of Bayesian methods. The first is the development of a generic or reference human error probability from different types and sources of information. The second is the extension of data classification techniques to capture analyst judgements and relax the requirements on data quality and quantity. The third area is exploration of the role of causal factors on performance. Dr. Mosleh then provided a discussion of the mathematics of Bayesian methods for HRA use, such as with Bayesian Belief Networks.

Dr. Hallbert then returned to the microphone to lead the final discussions of the meeting. He presented work on extending Bayesian methods for causal models and context in HRA methods. He discussed why the use of information about human performance in HRA is limited, and why they believe a Bayesian framework can be useful. He described the issue as relating the performance environment to the model of human behavior to predict the risk metric of interest. Dr. Hallbert then discussed the research on extending Bayesian methods to employ information about causal and contextual factors in HRA.

Dr. Hallbert illustrated the concepts through an example application to operator performance and PSFs. The purpose of the work was to identify a set of PSFs and a general model which they can test to assess their predictive validity. This research examined a set of 10 PSFs, and collected data from multiple crews and multiple scenarios to develop a model with demonstrated predictive ability.

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

- Dr. Apostolakis asked if the HERA project is recording successful human actions also. Dr. Hallbert answered affirmatively.

- Dr. Bonaca asked if the information in LERs is limited. Dr. Hallbert answered yes. Dr. Bonaca suggested that the INPO APIX system might be useful. Dr. Lois agreed, but added that the project in resource-limited at this point.

- Dr. Bonaca noted that many events are not reportable since operators correct mistakes before an incident can occur. Dr. Hallbert agreed, noting that this data is only the tip of the iceberg, and does not estimate the number of opportunities. Dr. Kress asked how then do they get the denominator for the fraction of failures. Dr. Hallbert answered that they don't, and can't, so must use a Bayesian approach rather than a frequentist approach.

- Dr. Apostolakis commented that the Bayesian approaches can be simple in concept, yet complex in practice.

Closing Discussions

Closing Comments and Observations From the Subcommittee Members

- Dr. Apostolakis reviewed the upcoming schedule for HRA interactions. He noted that the full Committee will review the evaluation of HRA methods in February. He suggested that the staff plan to discuss SPAR-H in the spring. He also asked them to suggest additional topics for review. The staff suggested the ATHEANA user guide and applications of ATHEANA.

- Dr. Bonaca expressed his appreciation of the method evaluation work and the best practices document. SPAR-H impressed him, despite its limitations. He would be interested in seeing a detailed application of ATHEANA. He also noted the Halden work as very interesting and expressed hope that the work might shed light on how to model individual characteristics within a team.

- Dr. Kress noted that the quantification of HRA is very important to risk analysis. He stated that the Bayesian work shows promise for quantifying the effects of PSFs. He seconded Dr. Apostolakis' comment that a focus on time would be good. He also agreed with the need to deal with the results of the ISPRA study.

- Dr. Apostolakis noted his appreciation for the staff and EPRI presentations. He sees a lot of value in the HRA Calculator. He sees a need to resolve ATHEANA vs. SPAR-H issues. He stated that Halden appears to be doing good work. He agreed with the value of the HRA method evaluation project, and added that he is in favor of benchmark exercises to compare methods. He also wants to see a response to the European Union HRA benchmark exercise.

SUBCOMMITTEE DECISIONS AND ACTIONS

The Subcommittee Members discussed future briefings by the staff on the topic of HRA. We have scheduled the HRA method evaluation project for the February 2006 full Committee meeting. We will schedule additional projects for the spring and summer. The Members expressed particular interest in SPAR-H and ATHEANA.

BACKGROUND MATERIALS PROVIDED TO THE SUBCOMMITTEE PRIOR TO THIS MEETING

Documents	
I.	None provided.
II.	None provided.
III.	USNRC, "Evaluation of Human Reliability Analysis Methods Against Good Practices," draft NUREG, 9 November 2005.
IV.	USNRC, "The SPAR-H Human Reliability Analysis Method," NUREG/CR-6883, August 20.
V.	Idaho National Laboratory, "Human Event Repository and Analysis (HERA) System," draft NUREG, INL/EXT-05-0586. Hallbert, Bruce, "Bayesian Methods Workshop Summary Report," November 2005.
VI.	Karin Laumann, Per Øivind Braarud, and Håkan Svengren, "The Task Complexity Experiment 2003/2004," HWR-758, OECD Halden Reactor Project, August 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.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

November 18, 2005

MEMORANDUM TO: Michael L. Scott, Branch Chief, ACRS/ACNW

FROM: Eric A. Thornsbury, Senior Staff Engineer

SUBJECT: FEDERAL REGISTER NOTICE REGARDING THE MEETING OF THE JOINT ACRS SUBCOMMITTEES ON RELIABILITY AND PROBABILISTIC RISK ASSESSMENT AND ON HUMAN FACTORS DECEMBER 15-16, 2005, ROCKVILLE, MARYLAND

Attached is a Federal Register Notice regarding the subject meeting. Please have this Notice transmitted for publication as soon as possible.

Attachment:
FR Notice

cc with Attachment:
G. Apostolakis, ACRS
J. Larkins, ACRS
J. Dixon-Herrity, OEDO
J. Szabo, OGC
A. Bates, SECY
S. Burnell, OPA
R. W. Borchardt, NRR
B. Boger, NRR
P. Hiland, NRR
C. Ader, RES
C. Paperiello, RES
PMNS
Public Document Room

[7590-01-P]

NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE JOINT ACRS SUBCOMMITTEES ON RELIABILITY
AND PROBABILISTIC RISK ASSESSMENT AND ON HUMAN FACTORS

Notice of Meeting

The ACRS Subcommittees on Reliability and Probabilistic Risk Assessment (PRA) and on Human Factors will hold a joint meeting on December 15-16, 2005, Room T-2B3, 11545 Rockville Pike, Rockville, Maryland.

The entire meeting will be open to public attendance.

The agenda for the subject meeting shall be as follows:

Thursday, December 15, 2005 - 8:30 a.m. until the conclusion of business

Friday, December 16, 2005 - 8:30 a.m. until the conclusion of business

The joint subcommittees will examine the current status of human reliability analysis including ATHEANA, SPAR-H, and industry approaches (if available). The Subcommittee will hear presentations by and hold discussions with representatives of the NRC staff and industry regarding this matter. The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee.

Members of the public desiring to provide oral statements and/or written comments should notify the Designated Federal Official, Mr. Eric A. Thornsbury, (Telephone: 301-415-8716) or Dr. John H. Flack, Senior Technical Advisor (Telephone: 301-415-0426) five days prior to the meeting, if possible, so that appropriate arrangements can be made. Electronic recordings will be permitted.

Further information regarding this meeting can be obtained by contacting the Designated Federal Official between 7:30 a.m. and 4:15 p.m.(ET). Persons planning to attend this meeting are urged to contact the above named individuals at least two working days prior to the meeting to be advised of any potential changes to the agenda.

11/21/2005
Date

Michael R. Snodderly
Michael R. Snodderly, Acting Branch Chief, ACRS/ACNW

Advisory Committee on Reactor Safeguards
Human Factors and Reliability & Probabilistic Risk Assessment Subcommittees Meeting
Rockville, MD
15-16 December 2005

- Proposed Agenda -
Rev 12/08/05
Cognizant Staff Engineer: Eric Thornsbury (301-415-8716, eat2@nrc.gov)

	Topic	Presenter(s)	Time
	December 15		
	Opening Remarks and Objectives	G. Apostolakis, ACRS M. Bonaca, ACRS	8:30 - 8:45 am
I	EPRI HRA Calculator	F. Rahn, EPRI Z. Elawar, PVNGS J. Julius, Scientech	8:45 - 10:30 am
	Break		10:30 - 10:45 am
II	Overview of Human Reliability Research Activities	J. Yerokun, RES E. Lois, RES	10:45 - 11:15 am
III	Evaluation of HRA Methods	E. Lois, RES J. Forester, SNL A. Kolaczkowski, SAIC	11:15 am - 12:30 pm
	Lunch		12:30 - 1:30 pm
	Evaluation of HRA Methods (cont)		1:30 - 3:00 pm
	Break		3:00 - 3:15 pm
IV	ATHEANA & SPAR-H	S. Cooper, RES M. Cheok, RES D. Gertman, INL	3:15 - 4:30 pm
V	HERA Data & Bayesian Methods all on Friday	B. Hallbert, INL A. Mosleh, UMD	4:30 - 5:45 pm
	Recess for the day		5:45 pm
	December 16		
	Reconvene		8:30 am
V	HERA Data & Bayesian Methods (cont)	B. Hallbert, INL A. Mosleh, UMD	8:30 - 9:45 am
	Break		9:45 - 10:00 am
VI	Halden Experiments	A. Bye, HRP	10:00 am - 1:00 pm
	Adjourn		1:00 pm

Notes:
- Presentation time should not exceed 50% of the total time allocated for a specific item.
- Number of copies of presentation materials to be provided to the ACRS - 35.

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON FUTURE PLANT DESIGNS

December 16 2005
Date

PLEASE PRINT

NAME	AFFILIATION
Bruce Hallbert	INL
Per Øivind Braarud	OECD Halden RP
Andreas Bye	OECD Halden Reactor Project
ALAN KOLACZKOWSKI	SAIC
JOHN FORESTER	SANDIA LABS
Zouhair Elawar	APS
Anne Robinson	TVA
Yung Hsien Chang	UMD

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON ~~FUTURE PLANT DESIGNS~~ HRA

December 15, 2005
Date

PLEASE PRINT

NAME	AFFILIATION
JOHN FORESTER	SANDIA LABS
ALAN KOLACZKOWSKI	SAIC
Bruce Hallbert	INL
DAVID GERTMAN	INL
Andreas Bye	Halden Project
Per Øivind BRAARUD	Halden Project
Kevin Coyne	NRC/Grad Fellow - Univ of Maryland
Anne Robinson	TVA
Ing Hsien Chang	UMD
JEFF JULIUS	Scientech LLC
FRANK RAHN	EPRI
Zouhair Elawar	APS (Palo Verde Nucl. Plant)

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON FUTURE PLANT DESIGNS

December 15, 2005
Date

NRC STAFF SIGN IN FOR ACRS MEETING

PLEASE PRINT

NAME	NRC ORGANIZATION
Peter Appignani	RES/DRAA/OERAB
Don Marksberry	RES/DRAA/OERAB
Garrett Parry	NRR/DRA
Erasmia Lois	RES/PRAB
Susan E. Cooper	RES/PRAB
Donnie Harrison	NRR/DRA/APLA
Jeff Mitman	RES/DRAA/OERAB
Don Dube	"
Richard Barrett	RES/DRAA
Nilesh Chokshi	RES/DRAA/OERAB
Charles Ader	RES/DRAA
Gary DeMoss	RES/DRAA/OERAB
See Meng Wong	NRR/DRA/APOB
Mike Cheok	RES/DRAA/OERAB
J. Persensky	RES/DRAA/PRAB

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON FUTURE PLANT DESIGNS

December 16 2005
Date

NRC STAFF SIGN IN FOR ACRS MEETING

PLEASE PRINT

NAME	NRC ORGANIZATION
Don Marksberry	RES/DRAA/OERAB
Erasmia Lois	RES/DRAA/PLAB
GARETH PIACRY	NRR/DRA
See Meng Wong	NRR/DRA

EHT

NUCLEAR REGULATORY COMMISSION

[Docket No. 72–27]

Pacific Gas and Electric Company; Notice of Issuance of Materials License SNM–2514 for the Humboldt Bay Independent Spent Fuel Storage Installation

AGENCY: Nuclear Regulatory Commission.

ACTION: Issuance of Materials License.

FOR FURTHER INFORMATION CONTACT: James R. Hall, Senior Project Manager, Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Telephone: (301) 415–1336; fax number: (301) 415–8555; e-mail: *jrh@nrc.gov.*

SUPPLEMENTARY INFORMATION: The U.S. Nuclear Regulatory Commission (NRC or the Commission) has issued Materials License No. SNM–2514 to the Pacific Gas and Electric Company (PG&E) for the receipt, possession, storage, and transfer of spent fuel at the Humboldt Bay Independent Spent Fuel Storage Installation (ISFSI), to be located in Humboldt County, California. This Materials License is issued under the provisions of Title 10 of the Code of Federal Regulations, part 72 (10 CFR part 72), and is effective as of the date of issuance. A license for an ISFSI under 10 CFR part 72 is issued for 20 years, but the licensee may seek to renew the license prior to its expiration.

The Humboldt Bay ISFSI is licensed to provide interim storage in a dry cask storage system for up to 31 metric tons of uranium contained in intact and damaged fuel assemblies and associated radioactive materials resulting from the operation of the Humboldt Bay Power Plant, Unit 3. The dry cask storage system authorized for use is a site-specific version of the HI–STAR 100 system, designated as the HI–STAR HB system, designed by Holtec International.

Following receipt of PG&E's application dated December 15, 2003, the NRC staff published a "Notice of Docketing, Notice of Proposed Action, and Notice of Opportunity for a Hearing for a Materials License for the Humboldt Bay Independent Spent Fuel Storage Installation" in the **Federal Register** on February 11, 2004 (69 FR 6701). In conjunction with the issuance of this license, the staff published a "Notice of Issuance of Environmental Assessment and Finding of No Significant Impact for the Humboldt Bay Independent Spent Fuel Storage Installation," in the **Federal Register** on November 16, 2005 (70 FR 69605). The staff's Environmental Assessment (EA) considered the impacts of the construction, operation and decommissioning of an ISFSI at the Humboldt Bay site, including impacts resulting from the use of the HI–STAR HB dry cask storage system. The staff has determined that no significant environmental impacts will result from the proposed Humboldt Bay ISFSI.

The NRC staff has completed its environmental, safeguards, and safety reviews of the Humboldt Bay ISFSI license application and safety analysis report, as amended. The NRC staff issued Materials License No. SNM–2514 and its Safety Evaluation Report (SER) for the Humboldt Bay Independent Spent Fuel Storage Installation on November 17, 2005.

Further details with respect to this action are provided in the application dated December 15, 2003, as amended October 1, 2004; the staff's EA, dated November 16, 2005; Materials License SNM–2514 and the staff's SER, dated November 17, 2005; and other related documents, which are publicly available in the records component of NRC's Agencywide Documents Access and Management System (ADAMS). These documents may be accessed through the NRC's Public Electronic Reading Room on the Internet at: *http://www.nrc.gov/reading-rm/adams.html.* These documents may also be viewed electronically on the public computers located at the NRC's Public Document Room (PDR), O1F21, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852. Persons who do not have access to ADAMS or who encounter problems in accessing the documents located in ADAMS, should contact the NRC PDR Reference staff by telephone at 1–800–397–4209 or (301) 415–4737, or by e-mail to *pdr@nrc.gov.* The PDR reproduction contractor will copy documents for a fee.

Dated at Rockville, Maryland, this 17th day of November, 2005.

For the Nuclear Regulatory Commission.

James R. Hall,

Senior Project Manager, Licensing Section, Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards.

[FR Doc. E5–6549 Filed 11–25–05; 8:45 am]

BILLING CODE 7590–01–P

NUCLEAR REGULATORY COMMISSION

Advisory Committee on Reactor Safeguards; Meeting of the Joint ACRS Subcommittees on Reliability and Probabilistic Risk Assessment and on Human Factors; Notice of Meeting

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Dated: November 21, 2005.

Michael R. Snodderly,

Acting Branch Chief, ACRS/ACNW.

[FR Doc. 05–23321 Filed 11–25–05; 8:45 am]

BILLING CODE 7590–01–P

EPRI HRA Calculator® Introduction

Frank Rahn, EPRI

NRC - White Flint

December 15, 2005

EPRI

Presentation Overview

- Introduction to EPRI HRA Users Group (Dr. Frank Rahn)
- EPRI HRA Calculator® Background (Dr. Zouhair Elawar)
- EPRI HRA Calculator® Status & Applications (Dr. Frank Rahn)
- EPRI HRA Calculator® Technical Description (Jeff Julius)
- Conclusions (Dr. Frank Rahn)

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EPRI

Presenters

- Frank J. Rahn – D. Eng. Sc., PE, Fellow of ANS
  - 31 years at EPRI
  - Manager of Risk Applications & Safety Codes
    - HRA Users Group
    - R&R Users Group
    - MAAP Users Group
    - GOTHIC Advisory Group
    - RETRAN & VIPRE Users Group
    - LOOP & Transmission Grid Initiatives
  - Columbia University Alumnus (MS and Dr. of Engineering degrees in Nuclear Engineering)
  - Tel: 650 855 2037
  - frahn@epri.com

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EPRI

Presenters

- Zouhair J. Elawar, D. Eng. Sc, PE
  - Senior PRA Engineer, Palo Verde Nuclear Generating Station (PVNGS)
  - 27 years Nuclear experience, 10 years PRA experience
  - Stanford University Alumnus (MS and Dr. of Engineering degrees in Mechanical Engineering)
  - HRA Users' Group Chairman
  - Tel: 623 393 5328
  - zelawar@apsc.com

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EPRI

Presenters

- Jeffrey A. Julius
  - EPRI HRA Users Group Project Manager
  - PRA Technical Manager, Scientech LLC
  - 25 years Nuclear experience, 19 years PRA experience
  - University of Washington Alumnus (BS in Engineering)
  - US Navy Nuclear Power Program Alumnus (Engineer Qualified, 1 Year as Prototype Training Instructor)
  - HRA Project Manager for 14 plants, reviewer at 10 plants
  - Author/co-author of 10 papers/articles on HRA
  - Tel: 206.248.1818 ext 230
  - jjulius@scientech.com

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EPRI

HRA Calculator® Project
Established 2001

- EPRI --- project manager on behalf of the industry
- HRA Users Group --- Utility group that provides guidance and resources to EPRI on industry needs and priorities, and beta testing of software prior to release
- Scientech --- Contractor to EPRI for technical work, including software development, maintenance and training
- Jointly funded work --- e.g. with Risk and Reliability Users Group
- Coordinated with other industry efforts
  - EPRI Advisory Committees
  - NEI
  - Owners Group
  - International Participants

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EPRI

Key EPRI HRA Research
over last 20 years

- Early EPRI HRA-related research includes:
  - SHARP (Systematic Human Reliability Procedure) EPRI Report NP-3583 (1984)
  - Human Cognitive Reliability (HCR) Model for PRA Analysis, EPRI Report NP-4531 (1984)
  - A Human Analysis Approach Using Measurements for IPE, EPRI Report NP-6560-L (1989)
    - Operator Reliability Experiments (ORE)
    - Operator Reliability Assessment System (OPERAS)
  - SHARP1 (Revised Systematic Human Reliability Procedure) EPRI Report NP-7183-SL (1990)

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EPRI

EPRI HRA Calculator®
Background

Zouhair J. Elawar, APS
Chairman of HRA Users Group
NRC - White Flint
December 15, 2005

EPRI

"Analyst" Factors in HRA
Prior to HRA Calculator

"Analyst" factors used to be very significant in the following areas:

- Selecting the appropriate pre-initiator and post-initiator methods
- Performance shaping factors: alarms, accessibility, training, procedure, work load, and other factors
- Operator stress level assignment
- Error factors and propagation of errors
- Available timing and event diagnosis timing
- Selecting the proper tables from THERP
- Recovery of errors and level of dependency between personnel
- Means vs. Medians
- Dependency between HRAs
- Consistency between similar HRAs
- HRA documentation

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EPRI

What is the EPRI HRA Calculator®?

- A software tool designed to facilitate a standardized approach to human reliability analysis (HRA).
- It is designed to meet utilities needs for all current and foreseeable PRA and regulatory needs
- Prior to the development of the HRA Calculator
  - Wide varieties of methodologies were used
  - The results could vary widely when comparing results between similar plants, or even when comparing the actions within the same plant that are evaluated by different analysts
- The HRA Calculator provides:
  - A nearly-universally used tool
  - Whose strengths and weaknesses are well understood
  - That provides an adequate and consistent HRA

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EPRI HRA Calculator®
Main Objective

- Ensure that a standardized tool will satisfy the HRA criteria of the American Society of Mechanical Engineers PRA standard.
  - The ASME PRA standard contains both "high level requirements" and "supporting requirements"
  - there are many possible ways to comply with the ASME PRA standard
  - Risk-informed PRA applications use the ASME PRA standard
- The HRA Calculator helps ensure PRA quality through consistency and uniformity
- The HRA Calculator is backed by a strong Users Group

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EPRI HRA Users Group Members

AEP	Jim Hawley, Steve Cherba, Yu Shen
Ameren UE	Keith Connelly, Mark Walz
APS	Zouhair Elawar
Constellation Energy	Jim Orr, George Lapinsky, Steve Kimbrough, Paul Jameson
Detroit Edison	Joe Lavelline, Jorge Ramirez, Michael Hall
Dominion	Song Hua-Shen, Fred Cietek, Barry Sloane, Tom Hook, Dave Bucheit
Duke	Duncan Brewer, Robert McAuley
EPRI	Frank Rahn
EXELON	John Steinmetz, Greg Kreuger
FENOC	Colin Keller, Sum Leung, Dennis Jondle
FPL	Ching Guey, Ken Kiper, Larry Rau, Mahmoud Heiba, Brien Vincent
NMC	George Baldwin, Jim Masterlark, Brian Brogan, Frank Yanik
NRC	Erasmia Lois
NPPD	Joe Edom
CANDU Owner Group/OPG/NSS	Keith Dinnie, Marcello Oliverio, Sugata Ganguli, Ranbir Parmar, Ben Hryciw
OPPD	Jay Fluehr, Alan Hackerott
PG&E	Amir Afzali, Nathan Barber
PSEG	Tom Carrier, Shahin Seyedhosseini
SAROS	Stuart Lewis
SCIENTECH	Jan Grobbelaar, Jeff Julius
SCE&G	Leo Kachnik
SCE	Michelle Carr, Parvis Moieni, Gary Chung
Southern	Anees Farruk, Young Jo, David McCoy, Ed Ingram, Owen Scott, Roger Hayes
STPNOC	Bill Stillwell, Roland Dunn, Alice Sun, Ray Fine
TVA	Bill Mims, Anne Robinson
TXU	Bob Lichtenstein, Dan Tirsun, Steve Karpyak
Westinghouse	David Finnicum, Gerard Samide, John Kitzmiller
Wolf Creek	Vern Luckert, JC Patel, David Alford

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EPRI HRA Users Group Mission

- Develop a tool to enable different analysis employing the same HRA method to obtain comparable results
- Provide an HRA interface with the R&R Workstation and similar PRA codes
- Improve the sensitivity analysis of Human Error Probabilities used in PRA models
- Develop standard guidelines for application of human reliability data, methods and performance shaping factors
- Satisfy the HRA Criteria of the ASME Standard
- Coordinate with EPRI, owners groups and NSNRC to develop guidelines and training materials
- Ultimately help industry converge on common methods

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EPRI HRA Users Group
HRA Calculator Applications

- HRA Update to PRA Standard
- Configuration Risk Management
- SDP Process
  - Add or alter recovery events
- Training
  - Including identification of PRA-important scenarios and procedures
- Licensing Issues
  - Impact of plant design modifications such as timing and instrumentation

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EPRI HRA Users Group Contact Information

- **Public website:**
  - www.epri.com/hra/index.html
  - Tell your non-HRA User Group friends!
- **Support website for HRA Users Group:**
  - www.epriweb.com/epriweb2.5/ecd/np/hra/index.html
  - Use for bug reporting, suggestions, downloads
- **For software support & user group suggestions:**
  - Jan Grobbelaar (jgrobbelaar@scientech.com) 800.862.6702
  - Jeff Julius (jjulius@scientech.com) on 800.862.6702
- **For EPRI project management support contact:**
  - Frank Rahn at 650 855.2037 or FRAHN@epri.com

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EPRI

EPRI HRA Calculator® Status & Applications

Frank Rahn, EPRI

NRC - White Flint

December 15, 2005

EPRI

EPRI HRA Users Group
Technical Approach

- Develop a software tool to meet the safety and regulatory needs of the nuclear plants
  - For immediate use by members
  - Defensible and reproducible
  - Report ready
- Develop a Uses Manual and Help supporting the software
  - Make software easy to use
  - Promote consistency
- Develop HRA Guidelines and conduct training
  - Promote consistency
  - Maps to ASME PRA Standard (directly and via EPRI's ePSA and Document Assistant)
  - Starting with Level 1 PSA, build the foundation for the future
    - SDP
    - Fire/flood
    - Shutdown

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EPRI HRA Users Group
Of Special Note

- The HRA UG works with universities to promote scholarship and student training
  - Software is available to schools at nominal cost
- The HRA UG is a focal point for providing feedback to NRC (on request) for draft reports
  - NRC Good Practices
  - SPAR-H
  - Human Event Repository and Analysis (HERA)
- The international membership of the HRA UG allows it to better monitor new developments in the field to ascertain if they would better serve the needs of the members
  - E.g., MERMOS methodology at EdF was explored

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EPRI HRA Users Group
HRA Models approved by Steering Committee

Pre-Initiator (Latent) HRA
- THERP Model (NUREG/CR-1278)
- ASEP Model (NUREG/CR-4772)

Post-Initiator (Dynamic) HRA
- CBDTM/THERP Model combination for Cognitive/Execution
  - Recommended for all human failure events
- HCR/ORE/THERP Model combination for Cognitive/Execution
  - Recommended for time-critical human failure events
- Annunciator Response model (NUREG/CR-1278) for skill-based, memorized actions
- CBDTM & HCR/ORE (EPRI TR 100259)
- THERP and Annunciator Response model (NUREG/CR-1278)

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EPRI HRA Users Group
New Software Features HRA Calculator® Version 3

- Dependency Analysis Function
  - Import cutsets
  - Find combinations
  - Identify dependencies
  - Facilitate quantification of conditional HEPs
- Tighter links between Performance Shaping Factors and Quantification
- Integration with the ASME PRA Standard requirements
- SPAR-H Model
- Next presentation – Summary of the functions and features of the EPRI HRA Calculator software

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EPRI HRA Calculator®
Technical Description

Jeff Julius, Scientech LLC

NRC - White Flint

December 15, 2005

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EPRI HRA Calculator®
Technical Approach

- Follows the SHARP/ASME general Process of Identification, Screening, Qualitative Characterization, Quantification, & Dependency Evaluation
- Allows for selection of methods
- Requires input of qualitative factors (Performance Shaping Factors)
- Consolidates voluminous hard-copy reports & tables into a single tool
- Promotes consistency by standardizing:
  - Definitions of qualitative performance shaping factors (for example timing terms)
  - Promoting guidelines for selection of PSF values / characteristics (for example, selection of THERP stress factor)
  - Suggesting limits affecting quantification (for example, limiting recovery to 1 means, limiting the dependency used in recovery based on time available, & minimum HEP level)

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EPRI

EPRI HRA Calculator® Software – Version 3.01 Functions and Features

- Pre-initiator (latent) HRA module
  - Procedure and LER Screening
  - ASEP
  - THERP
- Post-initiator (dynamic) HRA model
  - HCR/ORE
  - CBDTM
  - THERP
  - SPAR-H
- Dependency Analysis module
- Interfaces with R&R Workstation, WinNUPRA, generic
- Documentation in HTML, WORD, RTF

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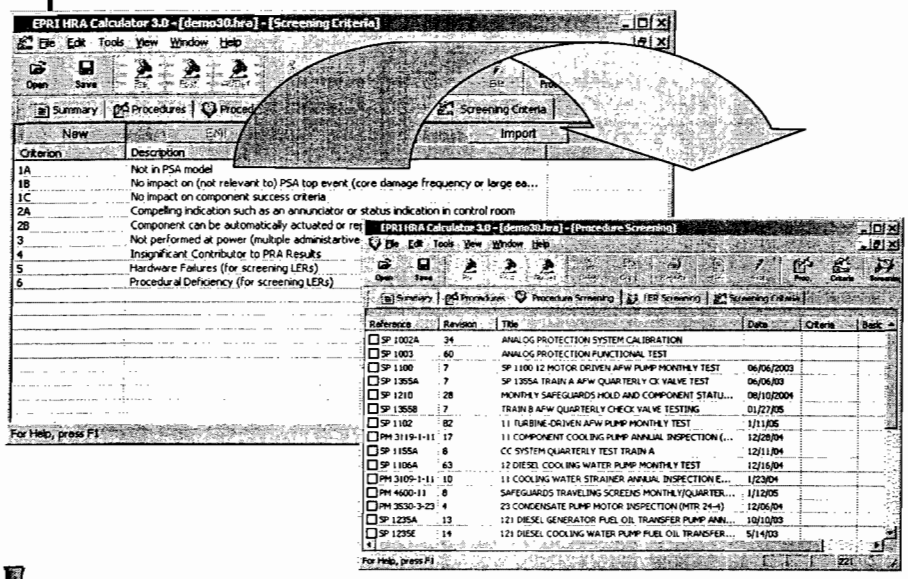
EPRI

Pre-Initiator Module: Screening



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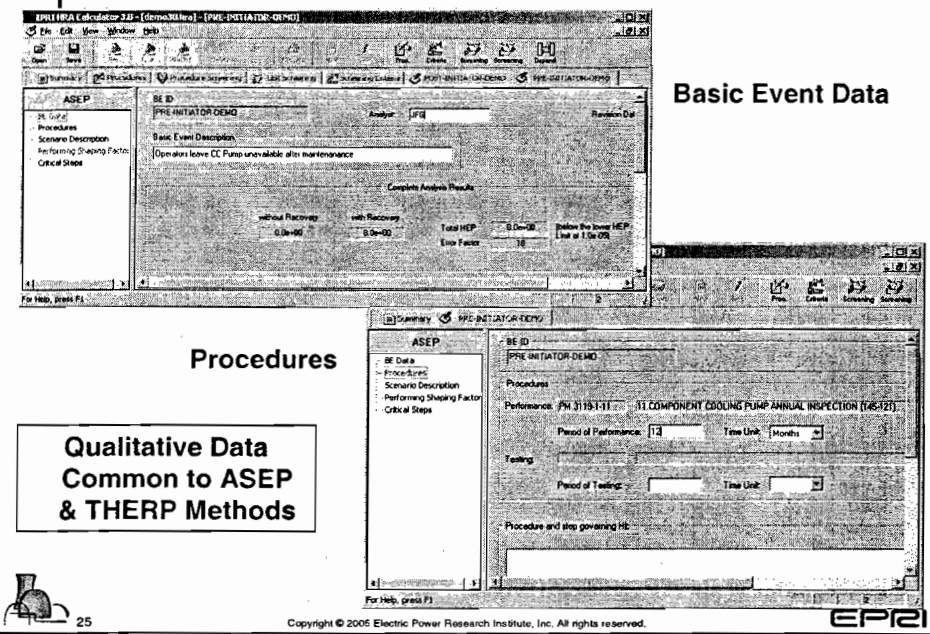
Pre-Initiator Module: BE Data & Procedures



Basic Event Data

Procedures

Qualitative Data Common to ASEP & THERP Methods

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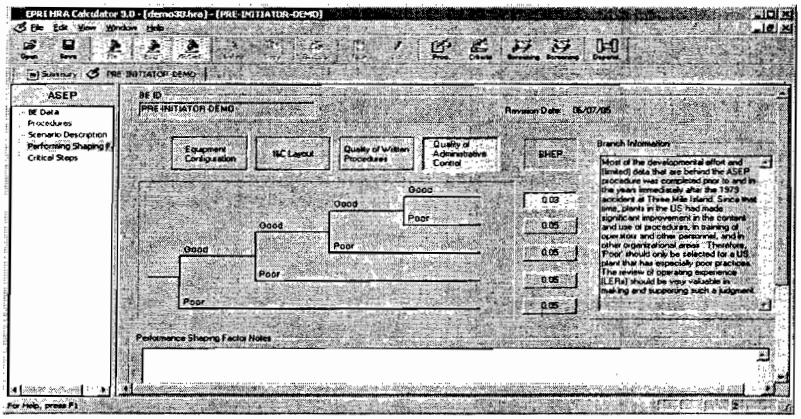
Pre-Initiator Module: Performance Shaping Factors Common to ASEP & THERP



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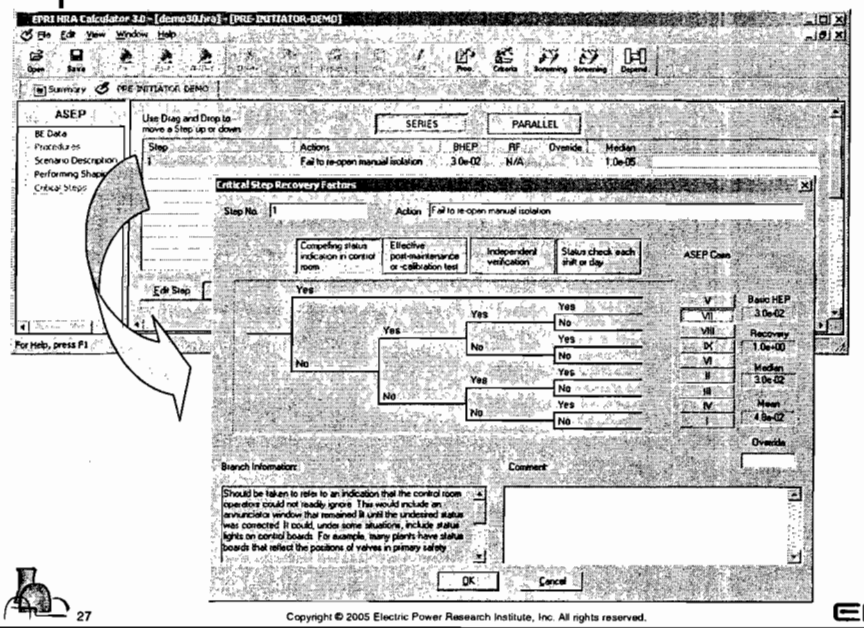
Pre-Initiator: ASEP Critical Steps & Recovery



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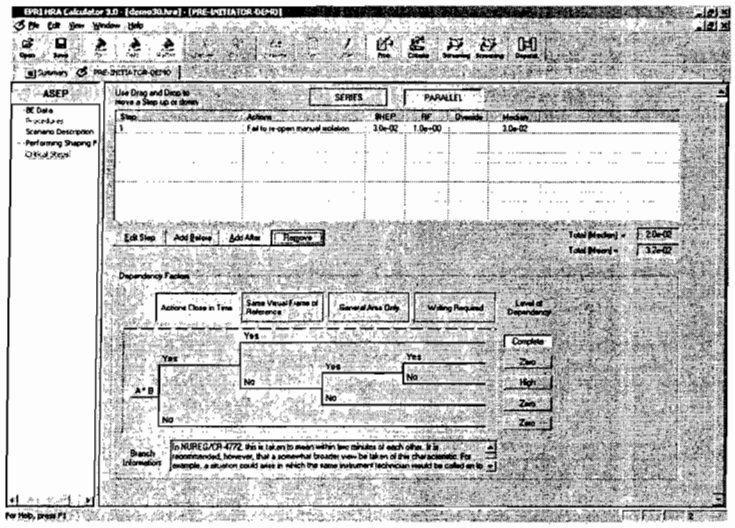
Pre-Initiator Module: ASEP Dependency Factors



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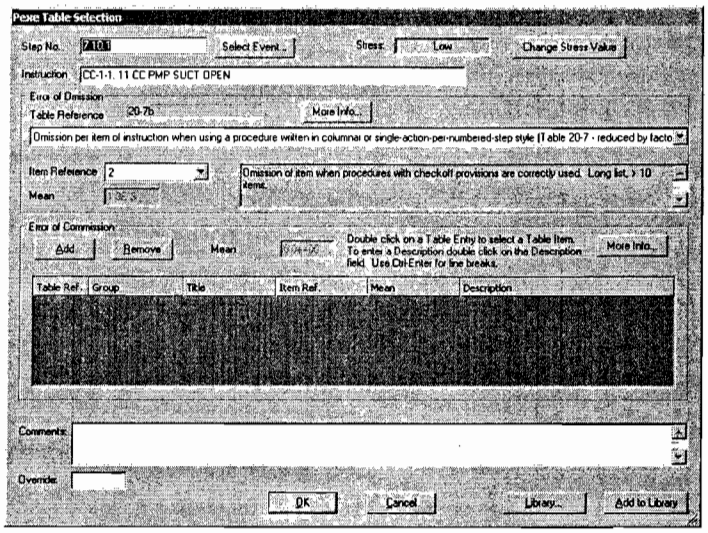
Pre-Initiator Module: THERP Method



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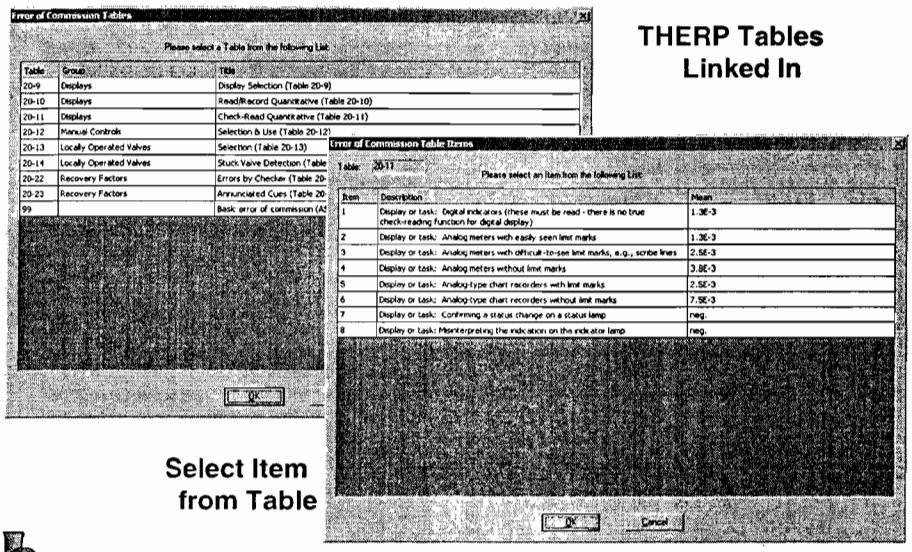
Pre-Initiator Module: THERP Table & Item Selection



THERP Tables Linked In

Select Item from Table

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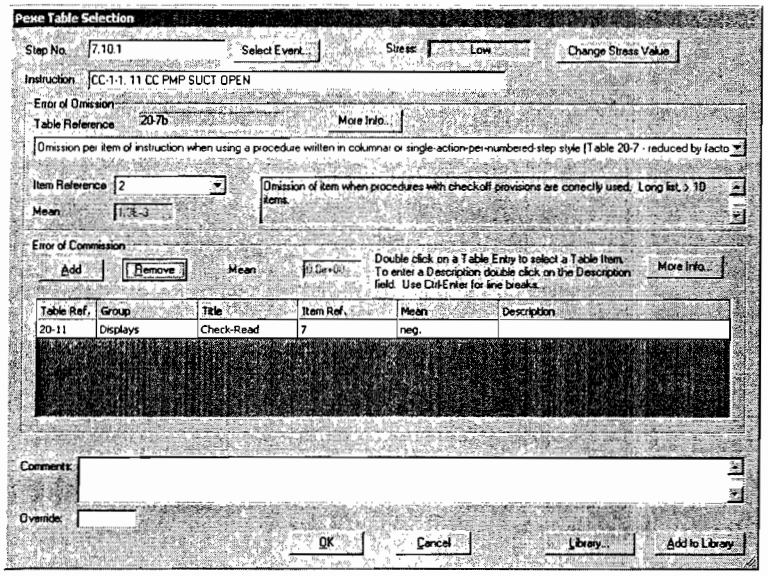
Pre-Initiator Module: THERP Multiple EOCs



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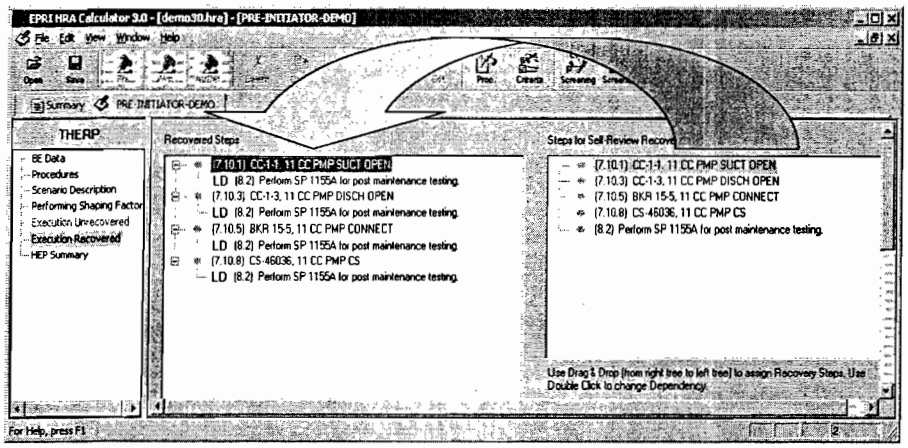
Pre-Initiator Module: THERP Logic Model



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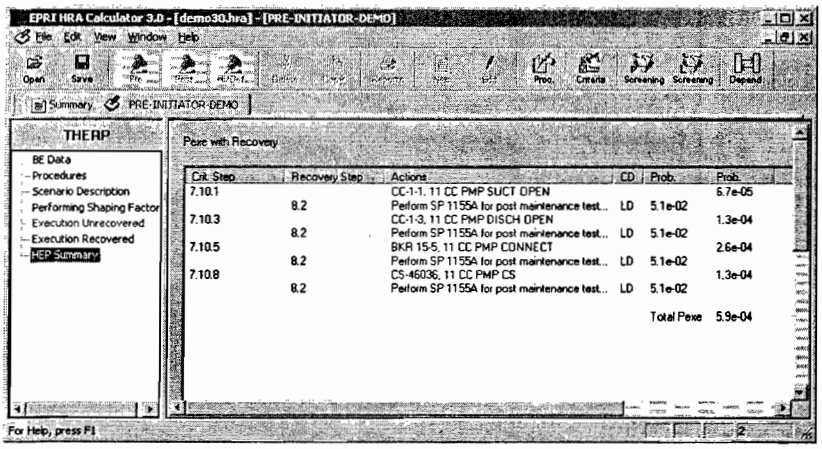
Pre-Initiator Module: THERP Summary



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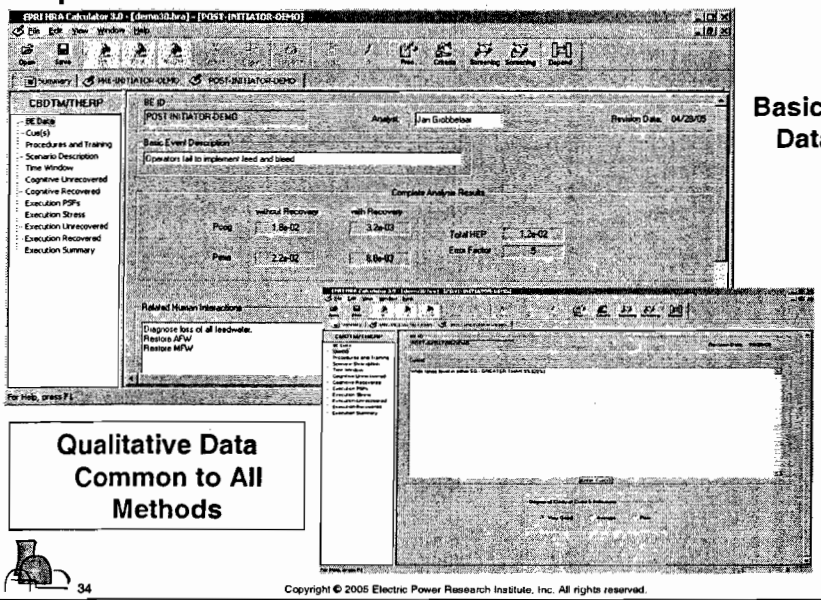
EPRI

Post-Initiator Module: BE Data & Cues



Basic Event Data

Cues

Qualitative Data Common to All Methods

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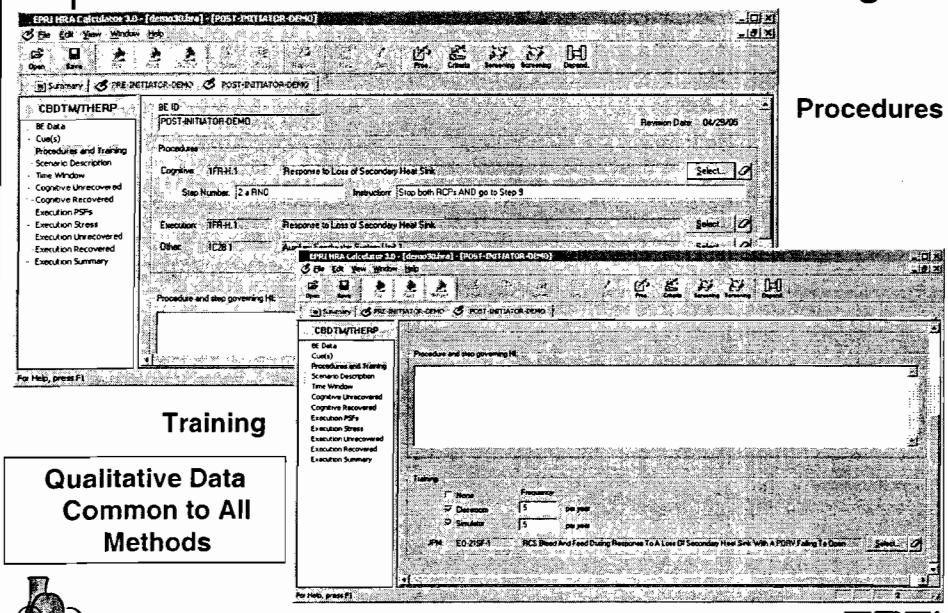
EPRI

Post-Initiator Module: Procedures & Training



Procedures

Training

Qualitative Data Common to All Methods

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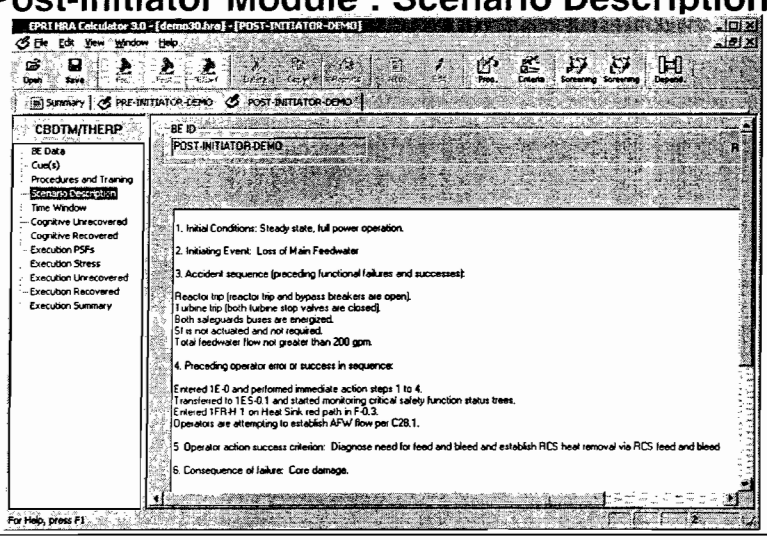
EPRI

Post-Initiator Module : Scenario Description



Scenario: Text Field able to provide Initial Conditions, Preceding Successes & Failures, Success Criteria, Operator Interview, etc.

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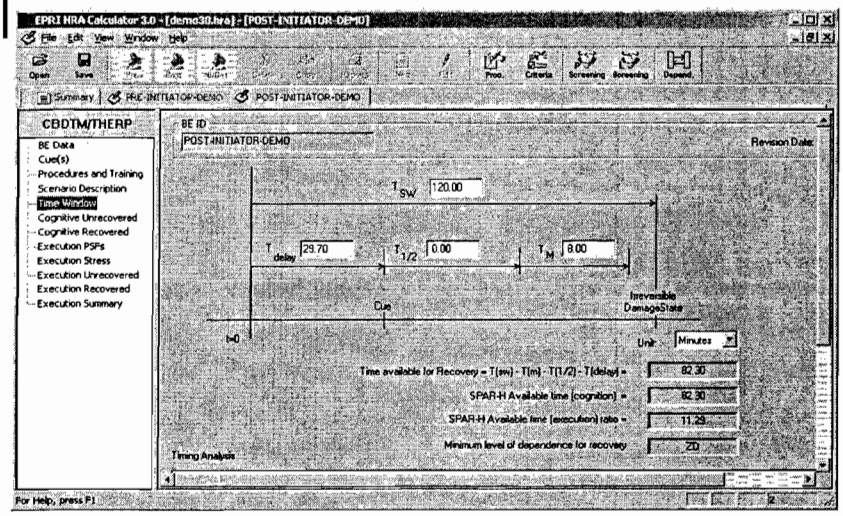
EPRI

Post-Initiator Module: Time Window



Common Timing Picture: System Time Window, Manipulation Time, Median Response Time, and Time Delays

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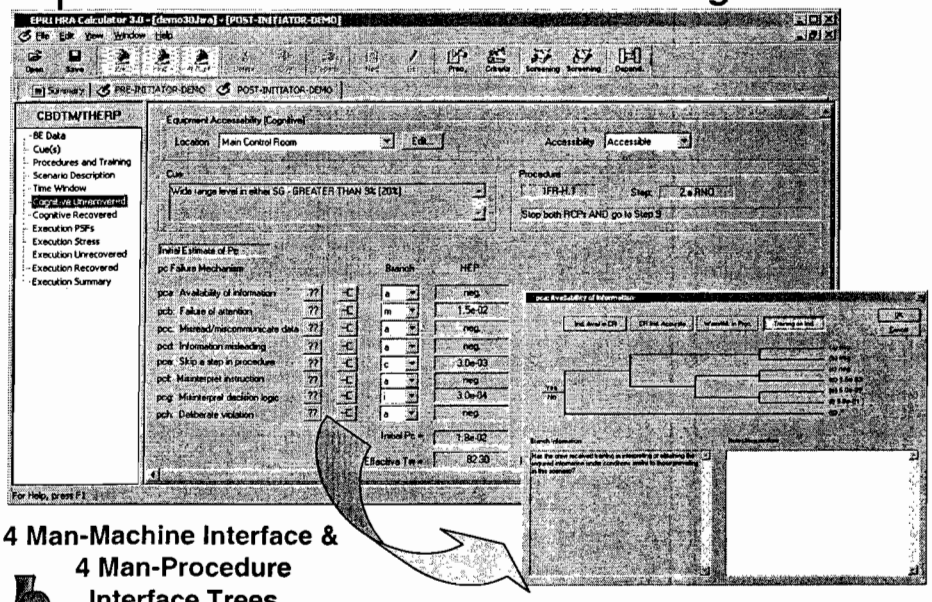
Post-Initiator Module: CBDTM Cognitive



4 Man-Machine Interface & 4 Man-Procedure Interface Trees

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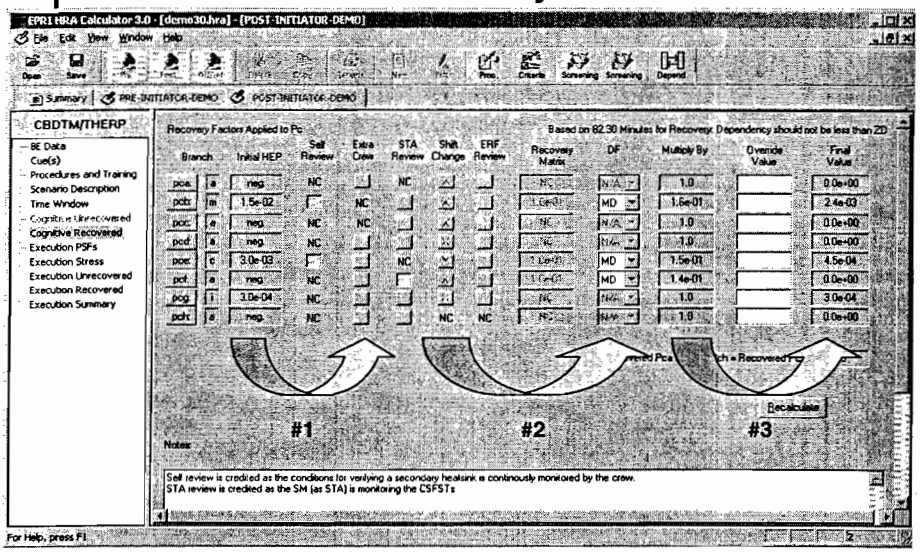
Post-Initiator Module: CBDTM Cognitive Recovery



#1-Initial Cog Failure, #2-Recovery Mechanism, #3-Dependency

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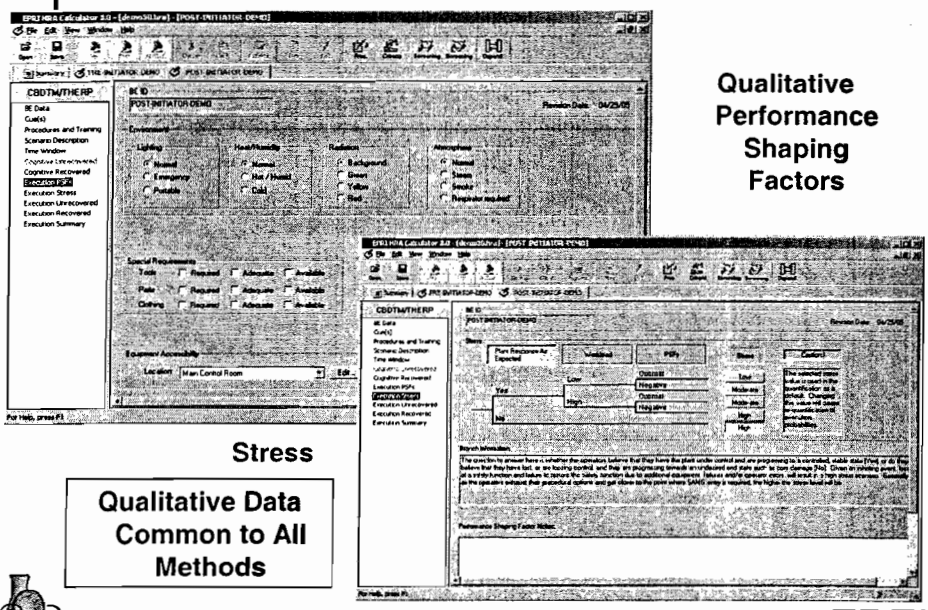
Post-Initiator Module: PSFs & Stress



Qualitative Performance Shaping Factors

Stress

Qualitative Data Common to All Methods

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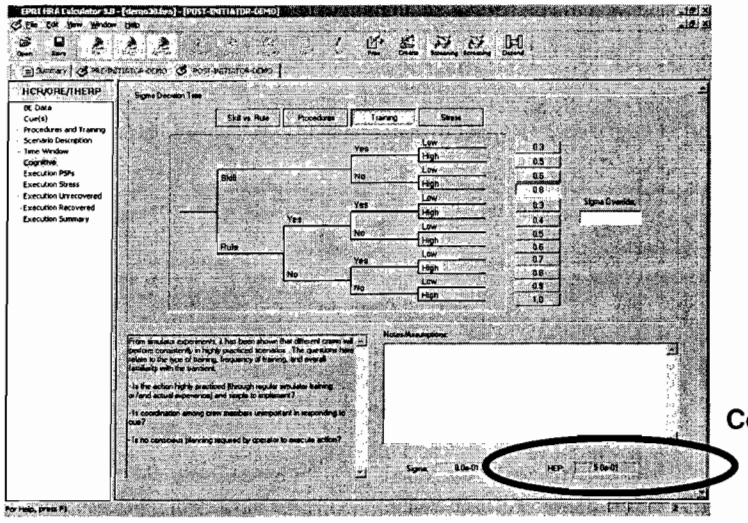
Post-Initiator Module: HCR/ORE



Cognitive HEP

#1- Timing Data implicitly addresses PSF, from Operator Interviews;
#2-Evaluate Sigma (variation between crews)

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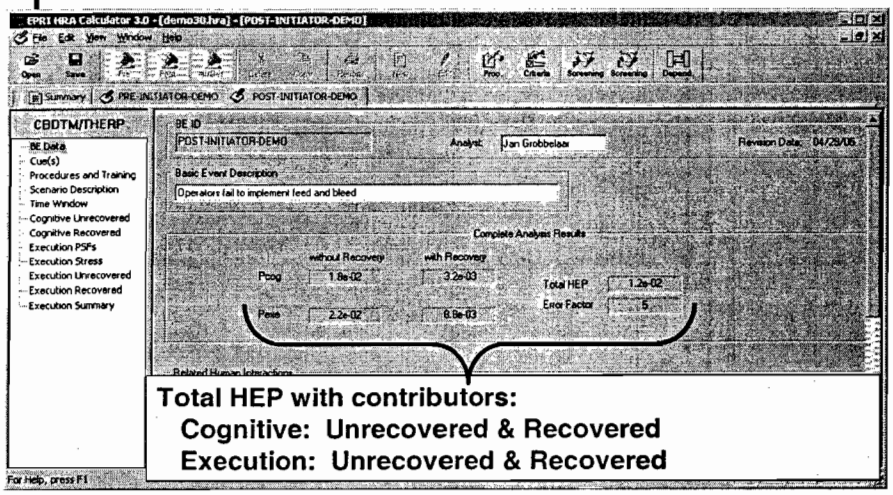
EPRI

Post-Initiator Module: Results Summary



Total HEP with contributors:
Cognitive: Unrecovered & Recovered
Execution: Unrecovered & Recovered

Provides Quantitative Human Error Probabilities
plus Qualitative Drivers;
Easy to Conduct Sensitivity Cases

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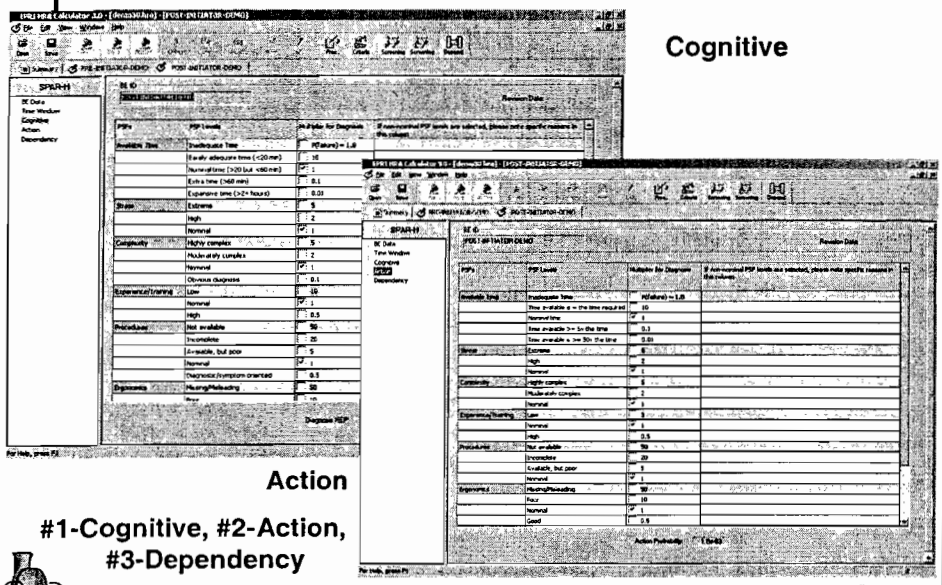
Post-Initiator Module: SPAR-H Cognitive & Action



Cognitive

Action

#1-Cognitive, #2-Action, #3-Dependency

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EPRI

Dependency Process

- Identification of Dependencies between Human Interactions
  - Starts with human failure event identification & qualitative definition (using PRA model & plant procedures)
  - Addressed during operator interviews
  - Checked with quantification results such as a cutset/sequence review
- Evaluation of Dependency Level
- Incorporation into Logic Model
  - Basic event consolidation, and/or
  - Conditional human error probabilities, and/or
  - Rule-based recoveries, and/or
  - Changes to fault trees

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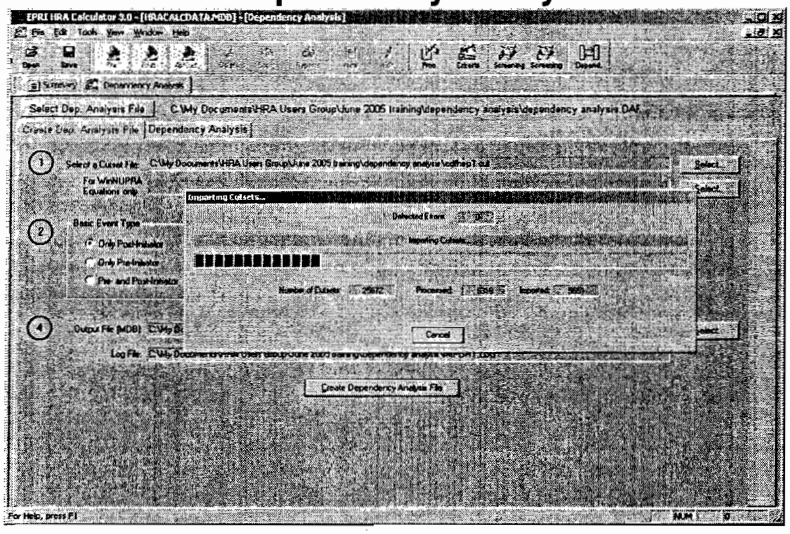
Dependency Analysis: Create Dependency Analysis File



Using a Cutset File and HRA Calculator Database

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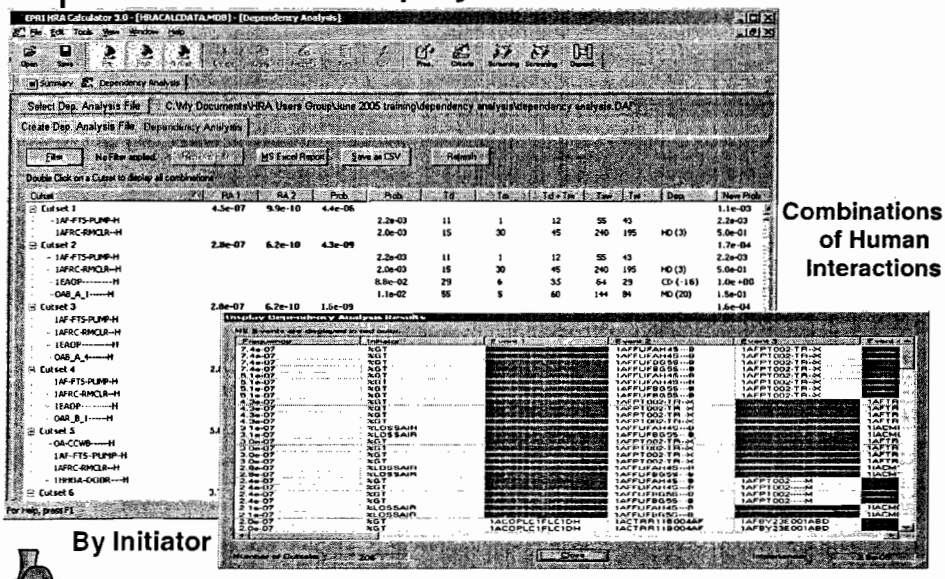
Dependency Identification: Display Results & Display Initiators



Combinations of Human Interactions

By Initiator

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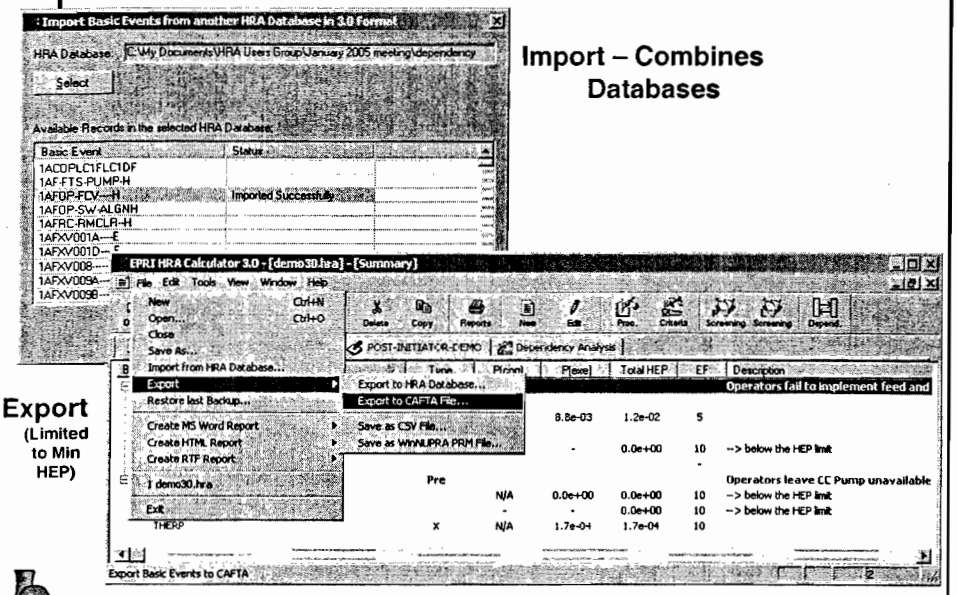
HRA Calculator® Interfaces: Import / Export



Import – Combines Databases

Export (Limited to Min HEP)

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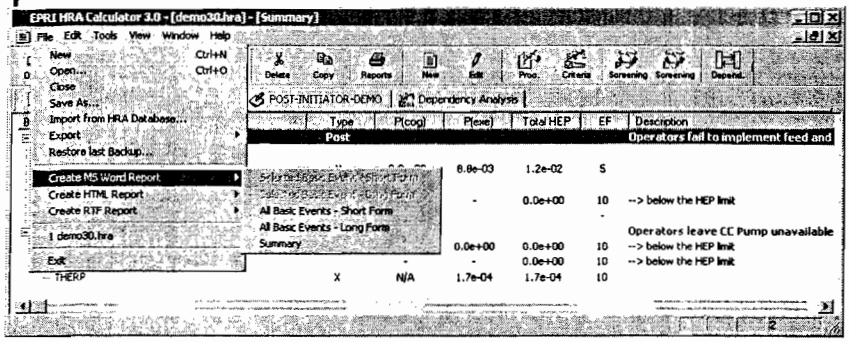
Documentation



Provides a written report for each Human Failure Event:

Documenting the Qualitative Factors used in the Characterization and the Method used in the Quantification of the Human Error Probability

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EPRI HRA Calculator® Conclusions

NRC - White Flint

December 15, 2005

EPRI

ACRS Presentation
Conclusions

- The HRA Users Group has worked for 5 years to improve the ability of utilities to do HRA. As a result most of the prior deficiencies have been corrected
- The HRA Calculator® approach satisfies the ASME PRA Standard and the NRC Good Practices in Implementing HRA
- The HRA Calculator® meets all the current and projected industry needs to do PRA and support regulatory requirements
- The project will extend its work beyond PRA level 1, internal events
- The project monitors research work by others to determine if other improvements can add value to its mission. Criteria:
  - Traceable
  - Defensible
  - Consistent

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EPRI

ACRS Presentation
Conclusions

- The Project has trained a dedicated core of utility analysts in its methods, and supports university research
- Training Tools (to ACAD standards) have been developed for in-house use
- A comprehensive set of guidelines complements the ASME PRA Standard
- Automatic links to all the commonly used PRA tools are available
- The Users Group invites NRC personnel to its meeting and appreciates any feedback it receives from the staff

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EPRI

EPRI

SCIENTECH®

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United States
Nuclear Regulatory Commission

Human Reliability Analysis Program

Jimi Yerokun
Erasmia Lois and Susan Copper
Human Factors and Reliability Section
PRAB/DRAA/RES

Presented to
Joint Meeting of Subcommittees on
PRA and Human Factors
Advisory Committee on Reactor Safeguards

Rockville, MD December 15, 2005

Briefing Objectives

- Provide an update on NRC's human reliability analysis (HRA) research programs
  - Obtain feedback/input to inform planning of HRA activities
- Address current interests of ACRS

HRA Research Program Goals and Objectives

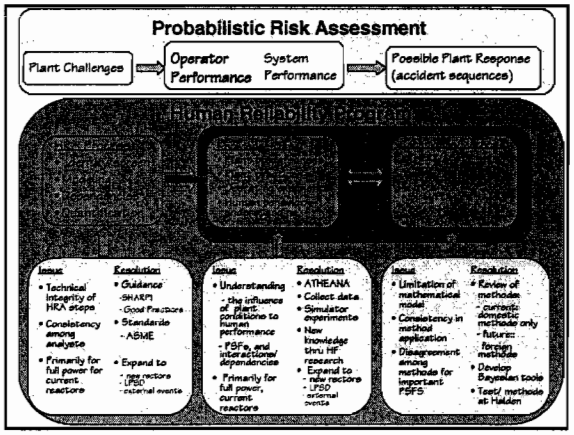
- Goal: Support risk-informed regulatory activities
  - Licensee requests for changes
  - Rulemaking
  - Licensing applications
- Objectives
  - Improve existing methods/tools
  - Technology transfer
  - Address emerging needs

HRA Research Program Goals and Objectives (continued)

- Major focus of current HRA research is to support NRC's action plan (SECY-0118, "Stabilizing the PRA Quality Expectations and Requirements") that includes addressing issues related to HRA
  - HRA Good Practices (NUREG-1792) – completed
  - Evaluation of HRA methods against good practices (in progress)
  - Development of data in progress

Briefing Overview

- Overview of the Human Reliability program
- Discussion of specific activities
  - HRA methods evaluation (with respect to HRA Good Practices, NUREG-1792)
  - HERA database
  - Halden activities
- HRA methods of interest
  - EPRI's HRA Calculator
  - ATHEANA & SPAR-H



Review of Human Reliability Analysis (HRA) Methods Against HRA Good Practices (NUREG-1792)

Erasmia Lois (USNRC)
John Forester (SNL)
Alan Kolaczkowski (SAIC)

Presentation to the Advisory Committee on Reactor Safeguards, PRA and Human Factors Subcommittees

Rockville, MD December 15, 2005

1

Outline

- Background
- Evaluation of Methods
  - HRA Process/Good Practices
  - Summary of Results
  - Discussion of each method
- Plans for next steps

2

Background

- The NRC has developed the "PRA Action Plan for Stabilizing PRA Expectations and Requirements," (SECY-04-0118) to address PRA quality issues
- Guidance for performing/reviewing HRAs is part of the plan
- Guidance is developed in two phases:
  - Phase 1: HRA Good Practices--NUREG-1792, completed
  - Phase 2: Evaluation of Methods Against the Good Practices, in progress
- Status of Methods Evaluation
  - Draft report submitted for internal review, including ACRS
  - Address comments/submit to ACRS full committee: February 2006
  - Submit for public comment: March 2006
  - Revise/submit to publication: September 2006

3

Approach for HRA Method Evaluation

- Compared methods, step-by-step with Good Practices
- External review of ATHEANA, SPAR-H, SLIM/FLIM
- Expert meeting to present initial evaluation/expert input
- Addressed recommendations
  - Look deeper to underlying technical basis (frameworks, models, data)
  - Discuss methods as intended to be used vs as practiced
  - Develop plan for next steps
- Revised reviews
- ACRS Subcommittees' review and feedback

4

Overview of HRA Steps/Good Practices

- Form HRA team
- Identify Human Failure Events
- Appropriately include in the model
- Identify Plant Conditions
- Identify Performance Shaping Factors (PSFs)
- Quantify
  - Considering Plant Conditions and PSFs
  - Address Dependencies

5

HRA Methods Reviewed

- Technique for Human Error Rate Prediction (THERP) (NUREG/CR-1278)
- Accident Sequence Evaluation Program (ASEP) HRA Procedure (NUREG/CR-4772)
- Human Cognitive Reliability (HCR)/Operator Reliability Experiments (ORE) Method (EPRI TR-100259)
- Cause-Based Decision Tree (CBDT) Method (EPRI TR-100259)
- EPRI HRA Calculator
- Standard Plant Analysis Risk HRA (SPAR-H) Method (NUREG/CR-6883)
- A Technique for Human Event Analysis (ATHEANA) (NUREG-1624, Rev. 1)
- Success Likelihood Index Methodology (SLIM) Multi-Attribute Utility Decomposition (MAUD) (e.g., NUREG/CR-3518)
- Failure Likelihood Index Methodology (FLIM)
- A Revised Systematic Human Action Reliability Procedure (SHARP1, EPRI TR-101711)

6

Summary of Results

- Most HRA methods are quantification tools for estimating human error probabilities (HEPs)
  - Provide guidance for obtaining HEPs
  - Do not address HRA process/good practices
- A few touch on some aspects of performing an HRA, but how to do a good HRA is left to analysts
- An exception is ATHEANA which provides both guidance and a quantification approach

7

Summary of Results

- EPRI early on developed guidance on how to do an HRA (SHARP/SHARP1)
  - Good job of covering many of the good practices related to identification and modeling
  - Insufficient guidance on identifying context and errors of commission
  - EPRI HRA methods typically reference these documents
  - Experience shows that SHARP/SHARP1 was not used widely/consistently

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Summary of Results (cont.)

- All HRA quantification methods have strengths and weaknesses
- Reflect an evolution in the thinking of how to quantify human failure
  - Early methods more simplistically address human behavior
  - Progression of methods reflects efforts to better understand/incorporate advances in behavioral/cognitive science and operational experience
  - Different approaches/capabilities for translating qualitative information into mathematical expression
- Different methods developed for different purposes (detailed versus scoping analysis)

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Summary of Results (cont.)

- Strengths, e.g.,
  - Some provide clear/good technical basis of underlying model
  - Good step-by-step guidance on how to use the tool
  - Traceable analysis
- Weaknesses, e.g.,
  - Weakness of the technical basis make the use of some methods questionable
  - Address only a limited set of performance shaping factors (PSFs) and context (plant conditions)
  - Methods not applied as intended

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Summary of Results (cont.)

- Overall perspective: Methods can be viewed as providing a "tool box" :
  - Some provide a tool for detailed analyses; others for screening analysis
- Using the right method for the right application is very important
- Therefore, we should use those methods that provide best capabilities for the application
- Should use methods as they are intended to be used
- Drop any method(s) found to have unjustified technical basis

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Findings of HRA reviews—method-by-method

- Scope of the method
- Underlying model/data
- Quantification approach
- Strengths and weaknesses

12

Scope
Technique for Human Error Rate Prediction (THERP) (NUREG/CR-1278)

- General guidance on identification and modeling (e.g., decompose operator tasks into subtasks)
  - How to incorporate into PRA not covered
- Guidance for quantification of pre- and post-initiator human failure events
- No screening human error probabilities (HEPs) for pre-initiators; post-initiator screening available, but more recently done using ASEP
- Diagnosis contribution to error is handled with time reliability curves (TRCs)
- Decomposes non-diagnosis HFEs into lower level errors via task analysis and identifies potentially important performance shaping factors (PSFs)

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Underlying Model/Data
THERP

- Human failure is treated considering a diagnosis contribution and an implementation (response execution) contribution – each quantified separately then added together
  - Diagnosis contribution uses a simple TRC model
  - Implementation contribution uses "nominal" HEPs that are adjusted to account for some PSFs
- Few HEPs and quantitative factors have an empirical basis
  - Values based mostly on expert judgments of the authors
  - Judgments from an understanding of human-machine interactions in industrial and military facilities, including nuclear power plants (mostly 1960's vintage)

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Quantification Approach
THERP

- TRC used to quantify diagnosis failure probability with some adjustment considering a few PSFs
- Implementation failure probability estimated using nominal HEPs selected for tasks and subtasks (based on tables that inherently account for some PSFs) that are then adjusted up/down to account for certain other PSFs, as well as dependencies among tasks/subtasks, and recovery
- Total HEP is equal to the sum of the diagnosis and implementation failure probabilities
- "Generic" uncertainty bounds are provided for all probability estimates (not necessarily relevant to actual context)

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Strengths and Weaknesses
THERP

Strengths

- Detailed task analysis can provide valuable qualitative insights
- Method has been applied widely, across industries, producing large pool of experienced analysts
- Good qualitative discussion of broad range of potentially relevant PSFs as well as how to identify failures of concern
- Explicitly handles diagnosis and implementation failures

Weaknesses

- Resource-intensive if performed as intended (so shortcuts often used)
- Not implemented as intended (e.g., use just the tables)
- Analyst may use the technique without HRA specialist leading
- TRCs for post-initiator diagnosis are based on expert judgment, used generically across all scenarios (one size fits all is probably not valid)
- Only a relatively small subset of PSFs actually addressed in quantifying HEPs (how to handle other PSFs left to analyst)

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Scope
Accident Sequence Evaluation Program (ASEP) HRA Procedure (NUREG/CR-4772)

- A quantification technique for pre- and post-initiator human failure events
- Provides both screening and nominal human error probabilities for both pre- and post-initiators
- Otherwise, a simplified version of THERP meant to be useable by PRA analysts with limited HRA background
  - ASEP is a self-contained technique with no specific use of THERP
  - Analyst does not need to "know" THERP

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Underlying Model/Data
ASEP

- Pre-Initiators
  - A generic error rate is used for all pre-initiator failures, which is modified by "checking-type" of recovery probabilities (e.g., 2nd checker, written checklist used)
- Post-Initiators
  - Diagnosis/implementation models similar to THERP
  - But…simplified treatment of factors affecting the HEP
    - Uses a simple representation of complexity of task (step by step or dynamic) and stress level for operator
    - Uses a simpler dependency treatment
    - Allows for additional recovery by other staff
- Quantitative values
  - Same basis as THERP
  - Adjusted somewhat to be more conservative

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Quantification Approach
ASEP

- Pre- and post-initiators quantified based on adjustment of a generic (for pre-) or initial (for post-) error rate (either a screening value or a nominal value) that is then adjusted based on a few PSFs and the simplifications mentioned earlier
- Diagnosis portion of post-initiator assessment uses TRCs just like THERP
- Uses just a fixed set of PSFs and limited guidance for applying them (via look-up tables and curves)
- "Generic" uncertainty bounds are provided for all probability estimates (not necessarily relevant to actual context)

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Strengths and Weaknesses
ASEP

Strengths
- Easy to use
- Simplified technique
- Leads to thorough analysis of pre-initiators
- Explicitly handles diagnosis and implementation failures
- Results are commonly accepted as reasonable for 'not far from average' context (i.e., conditions associated with the scenario and action of interest)
- Screening approach at least requires some analysis

Weaknesses
- Analyst may use the technique without HRA specialist input leading to possible misjudgments about the PSFs and relevant plant conditions
- Judgments about PSFs and context are made by the analyst with little guidance
- Cannot directly handle more extreme or unique PSFs and plant condition considerations due to the simplified underlying models and use of limited number of PSFs
- Same data limitations as THERP

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Scope
Human Cognitive Reliability (HCR)/Operator Reliability Experiments (ORE) Method (EPRI-TR100259)

- EPRI developed quantification technique for estimating non-response probability of post-initiator human actions only
  - Does not explicitly address human errors in diagnosis
  - Essentially assumes a correct diagnosis
- Provides both screening and nominal HEPs
- Includes Cause-Based Decision Tree (CBDT) method for longer time-frame events
- Assesses response execution errors separately

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Underlying Model/Data
HCR/ORE Method

- Simulator measurement-based, time/reliability correlation (TRC) for diagnosis portion of human action
  - Crew response time data can be fitted by a lognormal distribution which has the two parameters, T1/2 (median response time) and s (the logarithmic standard deviation of normalized time)
  - The probability of non-response within a time window can therefore be obtained from the standard normal cumulative distribution.
- Obtains estimates of crew response time for use in TRC
  - Plant specific simulations
  - Expert judgment from operators
  - Generalize from EPRI ORE data
- Probability of response execution failure is said to be based on relevant data from earlier simulator studies.

22

Quantification Approach
HCR/ORE

- Obtain estimates of critical parameters
- Only PSF directly considered is time-related, cue-response structure
  - Temporal relationship between alarms and indications and the need to respond, leads to different standard deviations
- All other influences assumed to be contained in estimates of median response time and response time variability

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Strengths and Weaknesses
HCR/ORE

Strengths

Use of empirical data is a strength if:
- Enough plant-specific simulator runs are conducted (but see first weakness)
- Assumptions about the underlying distribution for TRC are appropriate

Derivation of HEPs themselves straightforward and traceable
- it's the derivation of the parameters that is tricky

Weaknesses

In practice, analysts cannot or do not conduct enough simulator runs to address range of conditions and PSFs

Lack of guidance for obtaining expert judgments for crew response times

Generalizing ORE simulator results for plant-specific use is questionable

No systematic approach to identify human response vulnerabilities

*Weaknesses strongly question use of the method

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Scope
Cause-Based Decision Tree (CBDT) Method
(EPRI-TR100259)

- Originally developed by EPRI to:
  - Serve as a check on cases where the HCR/ORE approach has produced very low probability values
  - Address actions with longer time frames where "extrapolation using the lognormal curve (from the HCR/ORE TRC) could be extremely optimistic"
- Quantification technique for estimating non-response probability of post-initiator human actions only
  - Causal approach allows identification of potential error mechanisms
  - Factors that could contribute to failures in diagnosis are assessed
- Like HCR/ORE, assesses response execution errors separately
- In more recent years, the CBDT method has frequently come to be used as a "stand alone" method

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Underlying Model/Data
CBDT Method

- General causal model of human behavior involving decomposition into causes and human failure mechanisms in the form of decision trees.
- HEPs included in the method's decision trees are based on adaptation of data from THERP (NUREG-1278) to the conditions covered by the method.

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Quantification Approach
CBDT Method

- Uses a decision tree approach whereby analysts answer questions related to a set of influencing factors and resulting HEPs are provided.
- The HEPs obtained from the eight decision trees are allowed credit for "self" recovery by crew members if time permits.
  - The resulting HEPs are then summed together, along with an HEP for failure to execute the response, to obtain the final HEP

27

CBDT Decision Tree "Factors"

- Uses a series of decision trees to address potential causes of errors and produces HEPs based on those decisions.
  - Availability of relevant indications (location, accuracy, reliability of indications);
  - Attention to indications (workload, monitoring requirements, relevant alarms, etc.);
  - Data errors (location on panel, quality of display, interpersonal communications);
  - Misleading data (cues match procedure, training in cue recognition, etc.);
  - Procedure format (visibility and salience of instructions, place-keeping aids);
  - Instructional clarity (standardized vocabulary, completeness of information, training provided);
  - Instructional complexity (use of "not" statements, complex use of "and" & "or" terms, etc.); and
  - Potential for deliberate violations (belief in instructional adequacy, availability and consequences of alternatives, etc.).

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Strengths and Weaknesses
CBDT Method

Strengths	Weaknesses
• Use of causal model requires analysts to evaluate potential causes of errors	• No guidance for how to use method under time-limited conditions
• Ease of use of decision trees	• Although allows flexible selection and application of influencing factors, guidance to support this is not provided
• Allows flexible selection and application of influencing factors (beyond decision trees) as needed	• Assumption of independence among the various factors represented in the decision trees
• Suggests other factors not covered by decision trees may be relevant	• Potentially, the validity of adapting HEP data from THERP
	• Potential for optimism from misapplication of self recovery.

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Scope
EPRI HRA Calculator

- Software tool – not a method
- Automates use of HCR/ORE, CBDT, THERP annunciator response model, or SPAR-H to address diagnosis of post-initiators HFEs
- THERP for response execution portion if not using SPAR-H
- Uses THERP and ASEP to quantify pre-initiator HFEs
- Relies on SHARP1 as the HRA framework

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Underlying Model/Data, Quantification Approach
EPRI HRA Calculator

- No underlying model or data of its own (with one exception)
- Analysts interact with computer screens and provide data entries relevant to quantifying the human event, e.g. level of stress, time available.
  - Prompted entries per the selected methods
  - Software user's manual is provided
- Familiarity with the methods on the part of the analysts is assumed
  - User's guide to support HRA and use of the methods is planned

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Strengths and Weaknesses
EPRI HRA Calculator

Strengths

- Improves consistency in performing "mechanical" aspects of quantification, e.g., difficult to forget to address certain items
- Traceability and documentation is a positive as the software automatically stores and documents key inputs and results
  - Yet, level of detail on basis for selections up to the analysts
- Flexibility allowed to make changes to the basic model/data with good cause.
  - But not encouraged – standardization advocated, which is inconsistent with CBDT suggestions

Weaknesses

- Although proper training is encouraged, such a tool can promote its use by analysts without the proper HRA and human factors experience or oversight.
- No guidance for which method to use
  - CBDT default for diagnosis, whereas TR-100259 has HCR/ORE as primary
- Although allows flexibility to change models and adjust values, guidance to support this is not provided and not encouraged.
- Not all PSFs discussed/addressed in the software as part of the method used appear to be handled within the software quantification (i.e., info included for reference only)
- For HCR/ORE, introduces Sigma Decision Tree to obtain standard deviation based on whether action is skill-based or rule-based, nature of procedural guidance, extent of training, and stress (see next slide)

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Sigma Decision Tree
EPRI HRA Calculator

- If using HCR/ORE TRC, may use to obtain standard deviation based on whether action is skill-based or rule-based, nature of procedural guidance, extent of training, and stress
  - Offered as alternative to what was used in TR-100259 (cue-response structure)
  - Provides analysts a means of incorporating the effects of several performance shaping factors (PSFs) related to the "diagnosis" portion of the crew response
  - Represents a significant change in the approach
- Similar to what was used in original HCR model
  - EPRI ORE experiments argued that assumptions underlying the HCR model were not supported and dropped consideration of these aspects

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Sigma Decision Tree
EPRI HRA Calculator (continued)

- Unclear exactly how the data in the Sigma Decision Tree was derived (two important assumptions)
  - A basic assumption: following an initiating event, as the accident proceeds further into the response, one can expect to see larger deviations in crew response times
  - A large s can be indicative of difficult diagnosis, the need for deriving diagnoses by monitoring meters/alarms, or use of different response strategies. Thus, s is indicative of how demanding and stressful the scenario is for the operators
- Use of Sigma Decision Tree is questionable

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SCOPE
Standard Plant Analysis Risk HRA (SPAR-H) Method (NUREG/CR-6883)

- A quantification technique for diagnosis and action human failure events
- Can be used for pre- and post-initiator events although SPAR-H does not use that classification nor distinguish between the two
- Designed to provide reasonable estimates for regulatory uses such as evaluating the risk of plant events and conditions as part of the accident sequence precursor program (ASP) or in Phase 3 of the Significance Determination Process (SDP)

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Underlying Model/Data
SPAR-H

- Human failure is treated considering a diagnosis contribution and an action contribution – each quantified separately then added together
  - Both use an initial generic error rate
  - Generic error rate is modified using 8 PSFs for which a simple multiplicative model is used, with an additional adjustment when 3 or more negative PSFs are used
  - Further adjustments are made using the THERP dependency model with inherent consideration of recovery
- Error rates and their adjustments (to some extent) come from review of other HRA methods and the values they provide as a means to ensure some 'validity' (actually consistency) for values in SPAR-H.

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Quantification Approach
SPAR-H

- Start with generic error rate for diagnosis error (0.01) and action error (0.001)
- Determine each PSF level assignment which establishes multiplier to be applied to generic error rate
  - Each PSF quantitatively treated as independent
  - There is a discussion about interactions among PSFs but no explicit quantitative guidance for how to account for this
  - Additional adjustment made if there are 3 or more negative PSFs (hence accounts for some interaction at this level)
- Total HEP is equal to the sum of the diagnosis and action failure probabilities
- Further adjustment made for dependencies among tasks
- Result is treated as a mean value and uncertainty is represented with a constrained non-informative (CNI) prior distribution

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Strengths and Weaknesses
SPAR-H

Strengths

- Relatively simple to use
- The eight PSFs included may cover many situations where a more detailed analysis is not required
- Provides a detailed discussion of potential interaction effects between PSFs (but see related weakness)
- Explicitly handles diagnosis and action failures
- Some attempt to 'validate' values based on consistency with other HRA methods

Weaknesses

- Analyst may use the technique without HRA specialist leading to possible PSF/context misjudgments
- In spite of detailed discussion of potential interaction effects between PSFs, treats PSFs as independent
- Insufficient guidance for examining and understanding the scenario conditions that determine which levels of the PSFs are appropriate
- PSF dimensions have inadequate resolution for detailed analysis, e.g., all conditions that lead to judgment that procedures are "*available, but poor*" get the same multiplier.
- No explicit guidance for addressing a wider range of PSFs when needed

Scope
A Technique for Human Event Analysis (ATHEANA)
(NUREG-1624 Rev. 1)
(2004 Reliability Engineering &System Safety Article on Quantification)

- Identification, modeling, and quantification of post-initiator human actions, including treatment of errors of commission
  - Concepts applicable to pre-initiators, but little specific guidance provided
- Addresses potential cognitive failures for a human action, failures in implementing the desired action, and the situations that could cause them to occur
- Strives to address a wide range of performance conditions and failure modes (unsafe actions)
- Intent is to address both nominal and deviation scenarios (i.e., not just "near-average" context)

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Underlying Model/Data
ATHEANA

- Based on behavioral sciences view of human performance being in 4 stages
- The detailed context development process in ATHEANA (i.e., defining plant conditions and PSFs that are associated with the scenario for the action of interest) is designed to find reasons why a failure in any of the stages might occur.
- Since the HEP estimates come from a group consensus, expert elicitation process, judgment is used in the quantification process
  - Judgment is to come from qualified experts (e.g., operators) who are knowledgeable about the action and scenario of interest.
  - Their judgments are based on the information ("data") collected about the action using ATHEANA search process, their own experience, and industry experience (as passed on in ATHEANA training and in NUREG-1624), particularly about events that resulted in undesired consequences

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Quantification Approach
ATHEANA

- Uses a formal, facilitator-led expert elicitation process with experts particularly knowledgeable of the actions and scenarios of interest (typically persons from the operational and training staffs)
- Based on consideration of the factors deemed to have the most influence on the action of interest as derived during the context development process
  - A pre-set list of PSFs is not used, although guidance for the range of factors to be considered is provided.
  - Potentially relevant factors are considered "together" by the experts as opposed to individually
  - Important (driving) factors are identified based on the scenario context (the relationship between plant conditions and potential PSFs)
- Estimates cover the entire distribution for the HEP to account for epistemic and aleatory uncertainties

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Strengths and Weaknesses
ATHEANA

Strengths

- Among the most thorough context developing HRA methods, investigating behavior influencing factors beyond those considered in most (if not all) other methods. Strives for realism and identifying error-forcing conditions.
- Includes consideration of a reasonable range of different conditions (called deviations) as part of the context, and not just the condition of the plant as specified by the PRA model. This is done to capture the effects of aleatory uncertainties not treated in other methods nor typically in the PRA.
- More relevant uncertainty evaluation that considers the specific HFE and its context rather than the use of "generic" uncertainty bounds as is done in many other methods.
- Highlights need to consider and examine errors of commission.

Weaknesses

- If not documented thoroughly, the origins of the HEP estimates from the experts can be obscure and therefore difficult to reproduce or review.
- Detailed context development to determine the most appropriate influencing factors to be considered during quantification, can be complicated and time and resource intensive
- Consideration of "deviation" scenarios can add time
- Guidance for addressing the broad range of factors relevant to the nominal case needs to be strengthened
- More guidance for transforming scenario information into HEPs is needed.

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Scope

Success Likelihood Index Methodology (SLIM) Multi-Attribute Utility Decomposition (MAUD) and Failure Likelihood Index Methodology (FLIM)

- Quantification methods with a primary focus on post-initiator diagnosis failures
  - In principle, could be applied to any type human failure event
    - Pre-initiators, response implementation, and errors of commission
    - Little guidance for these types of actions. It is up to the analysts to define the event being quantified.
- FLIM (developed by PLG) is based on SLIM with the main distinction being that FLIM provides scaling guidance for a suggested 7 PSFs (in some applications more)

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Underlying Model/Data

SLIM and FLIM Methods

- Assumes that relative importance weights and ratings of PSFs, obtained from expert judges and related to a task, can be multiplied together and then summed across PSFs to arrive at the Success Likelihood Index (SLI).
- Using events with known HEPs as calibration events (anchor values), and an assumption of a logarithmic-linear relation between the desired HEP and the SLI, HEPs for specific events are obtained.
- Since the HEP estimates ultimately come from expert judgments, the underlying data is the information about the event and the PSFs, the "anchor values," and the experience of the judges.

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Quantification Approach

SLIM and FLIM Methods

- Expert judges identify the PSFs relevant to the events they are quantifying
- Weight and rate the PSFs in terms of their influence on an event
- Calibration values are identified and used in conjunction with obtained SLI for the event, in order to derive the HEP

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Strengths and Weaknesses

SLIM and FLIM Methods

Strengths

- In principle, allows consideration of a wide range of PSFs
- Use of a mathematical formula provides a traceable derivation of the obtained HEPs, as long as the basis for the weights and ratings of PSFs are thoroughly documented.
- Use of expert judges lends credence to the results.
- For FLIM, the inclusion of the PSF scaling guidance for the seven PSFs
  - Supports the expert teams in considering each PSF comprehensively
  - Including the identification of particularly adverse or "error-forcing" conditions

Weaknesses

- Identifying appropriate calibration data can be problematic
- Some artifacts of the multiplying and summing of PSF may distort the results
- In SLIM, lack of guidance for scaling the various PSFs
- Questions regarding the appropriateness of the linear model to reflect the experts' judgments
- Software tool for SLIM/MAUD not available?

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Scope

A Revised Systematic Human Action Reliability Procedure (SHARP1, EPRI TR-101711)

- SHARP1 is a guidance document for performing many aspects of an HRA in the context of a PRA (including identification and modeling issues)
- Covers both pre- and post-initiator human actions.
- While it does not provide a quantification method for either, it does provide a summary of quantification methods available at the time.
- Generally consistent with the ASME standard for performing an HRA and with the NRC's HRA good practices guidance

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Underlying Model/Data

SHARP1

- SHARP1 is a process or framework for performing HRA - it does not really have an underlying model or "data."
- Objective is to provide guidance to help ensure that the HRA is performed appropriately in the context of a PRA.
  - SHARP/SHARP1 do a very good job of covering many of the good practices related to identification and modeling of human actions, and consideration of dependencies
  - Insufficient guidance on identifying context and errors of commission
- Following its guidance should strengthen the validity of the results of an HRA, regardless of the quantification method used.

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Strengths and Weaknesses

SHARP1

Strengths

- SHARP1 provides good guidance for performing the "overall" HRA analysis, with only more recent HRA methods addressing a few aspects not addressed or covering a few in more detail.
  - Yet, none of the more recent methods address all of the aspects covered by SHARP1.
- Although it does not provide a quantification process, it leads analysts to identify and consider important information relevant to performing quantification of modeled human actions

Weaknesses

- It might be argued that a limitation of the method is that it does not provide enough guidance for how some of the information obtained using the method can be used in the context of many of the existing quantification methods.
- Lack of guidance on the many uses of simulator exercises to obtain important information.
- Insufficient guidance on identification of PSFs and context.
- Insufficient guidance on the consideration of errors of commission.

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Next Steps

- May need to develop a regulatory guide and/or SRP addressing method suitability/implementation for regulatory uses
- Continue improvement methods thru reviews of non USA methods and interactions with their developers
- Strive for convergence in HRA technology
  - Develop common frameworks—work with domestic and international experts/practitioners
  - Address the ISPRA study results
- Improve the technical bases of methods
  - Test/compare methods thru simulator experiments and other means
- Improve quantification capability
- Expand knowledge base as needed

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ATHEANA and SPAR-H: SUMMARIES

Susan E. Cooper, RES
Mike Cheok, RES
David Gertman, INL

December 15, 2005

Objectives/Uses of ATHEANA and SPAR-H

- ATHEANA
  - Full-scope, 2nd generation method (e.g., error perspective, knowledge-base, process steps, quantification approach)
  - Designed to support detailed HRA/PRA evaluations
  - Other uses performed/in progress (but not formally described)
  - Best used to treat special issues in HRA/PRA (e.g., pressurized thermal shock, steam generator tube rupture)
- SPAR-H
  - Simplified method (with modeling & analysis limitations)
  - Designed to be used with SPAR models in performing risk evaluations of operational events
  - Consistent, easy-to-use method

ATHEANA HRA METHOD

Susan E. Cooper, RES
December 15, 2005

ATHEANA

- What is ATHEANA?
- Why was ATHEANA developed?
- How has ATHEANA been used?
- How could ATHEANA be used?
- Future plans for ATHEANA

What is ATHEANA?

- A perspective on why serious accidents occur
- An approach for analyzing accidents, retrospectively (i.e., event analysis)
- A prospective HRA approach, including:
  - A process for performing HRA (i.e., both *qualitative* & *quantitative* HRA)
  - A formal search scheme for identifying human failure events
  - A systematic search scheme for error-forcing contexts
  - A "quantification-with-uncertainty" approach

Why was ATHEANA developed?

- To improve the state-of-the-art in HRA
- To incorporate the current understanding of why human errors occur,[1] based on recent advances in behavioral & cognitive science
- To realistically represent human behavior in accidents & near-miss events (substantiated by reviews of significant accidents both within & without the nuclear power industry)

1 Significant human errors usually occur because humans are "set up" for failure. The "set-up" consists of a combination of factors that together are defined as an "error-forcing context" - plant conditions and associated (or triggered) human-related factors (e.g., traditional performance shaping factors).

Why was ATHEANA developed?
(continued)

- ATHEANA provides the following improvements or new "tools" for HRA:
  - A formal description of how to perform HRA (later, used as the basis for HRA Good Practices, NUREG-1792) *Improvement*
  - A systematic search process for identifying human failure events, including errors of commission *New*
  - A perspective and formal approach for identifying accident scenarios involving *human* (not *hardware)* vulnerabilities *New*
  - A quantification approach that is flexible enough to address whatever factors (e.g., plant conditions, performance shaping factors) are considered important influences on human performance/reliability *Improvement*
  - A formal approach to treating uncertainty (i.e., quantification-with-uncertainty) *New*
  - A technical basis to support the current perspective on perspective on why human failures occur and how they contribute to serious accidents. *Improvement*

How has ATHEANA been used?

NRC applications:
- Recent Pressurized Thermal Shock HRA/PRA studies
- Basis for NRC's HRA "Good Practices" guidance (NUREG-1792)
- Basis for joint NRC/EPRI fire HRA/PRA methodology
- Using in Steam Generator Tube Rupture HRA/PRA study (in progress)
- Using general approach in NMSS spent fuel handling project (in progress)
- Using ATHEANA perspective in developing job aids for NMSS byproduct materials staff (in progress)

Examples of applications outside NRC:
- Chem DeMil HRA/PRA for Pueblo design
- Perspective used in various medical applications
- Perspective used in railroud applications

Future plans for ATHEANA

- Principal focus is "technology transfer"
  - Draft ATHEANA User's Guide
  - Review of User's Guide (internal & external)
  - Finalize User's Guide
  - "Training" workshops
  - Other "spin-off" products (e.g., retrospective analysis, screening approach)
- Identify additional, appropriate applications of ATHEANA

Future plans for ATHEANA
(continued)

- Examples of possible NRC applications of ATHEANA are:
  - HRA/PRA of advanced reactor designs
  - Retrospective analyses of NPP events
  - Any detailed HRA/PRA application (especially for "new" issues)
  - Basis for NMSS' review of Yucca Mountain HRA
  - Retrospective analyses of NMSS byproduct materials events

SPAR HRA

US NRC Presentation to the ACRS

David I Gertman

December 15 2005

Highlights for Discussion

- Why SPAR-HRA?
- PSFs used in SPAR-HRA
- Comparisons with other HRA methods, including quantification approach
- Comparison with experimental or experiential data

Why SPAR HRA?

- In 1994, the NRC ASP Program was using 4 formal rules and 1 heuristic for HRA (range from 1.0E-3 to 1.0)
- NRC requested that INEEL recommend or develop a method to allow for more realistic analysis of human error
  - Reviewed HRA methods, - - too detailed, too resource intensive to apply easily
  - Informed by 2nd generation and international developmental activities
    - Including ATHEANA concepts

SPAR-HRA Meets ASP Programmatic Requirements

- Based on an amalgamation of other HRA methods
- Easy to use
- Simplified approach
- Analysis can be completed in short time (If a full scope, detailed HRA is needed, other existing methods should be used)
- Ensure relevant PSF factors are addressed/accounted for
- Appropriate for most human behavior
- Used extensively with SPAR models, by the SDP program, and in risk analyses of operational events

Assumptions

- A simple model of human behavior is adequate
- Model is based on human performance and cognition; not on a specific plant condition
- PSFs can be identified that influence decision making and actions and cover each stage of the human behavior
- Plant conditions, tasks, people, and situations combine to create a context described by PSFs that influence performance

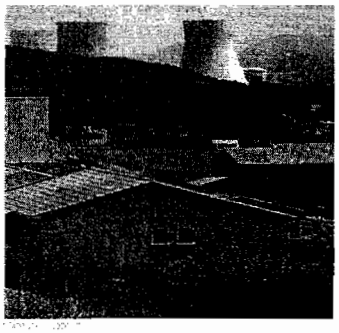
PSF Approach

- Influences are theory and model based
- Reflects PSFs used in many current HRA approaches
  - Influence ranges are calibrated
  - PSFs are reduced to a set of 8
- Existing literature supports SPAR-HRA PSFs

SPAR-HRA NUREG/CR- 6883 (2005)

- Updates and refines earlier PSF definitions
- Incorporates positive and negative effect of PSFs
- Provides work sheet examples
- Offers improved uncertainty approach
- Provides more technical basis information on PSFs and how the analyst should apply thresholds
- Extends SPAR-HRA to LP/SD
- Provides findings for calibration against other HRA methods

END



Halden experiments, Data for HRA

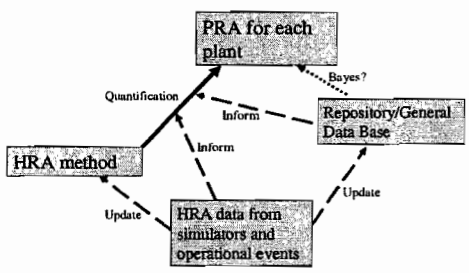
Andreas Bye, Per Øivind Braarud
OECD Halden Reactor Project

Advisory Committee on Reactor Safeguards
Human Factors and Reliability & Probabilistic Risk Assessment
Subcommittees Meeting, Rockville, MD
15-16 December 2005

Outline

- Role of data in HRA
- Last HAMMLAB (HAlden huMan-Machine LABoratory) experiment
  - Purpose
  - Method
  - Results
- Summary and next steps

Role of data in HRA



HRA data from simulators

1. Inform HRA practitioners in the use of HRA methods
2. Inform HRA method development
3. Input to generic DB/repository for use in quantification

1. Inform use of HRA methods

- Occurrence of Context
  - *"Will time pressure occur?"*
  - Subjective/objective PSF importance, when is a PSF present?
  - How does scenario develop based on variability of crew?
- Influence of Context on Human Failure/Performance
  - *"Given high time pressure, what is the effect on the operator (variability)?"*
  - What is time pressure "limits" that influence performance?
  - Threshold differences in human performance, e.g., when to use which levels of PSFs, how much emphasis to put on context (also for expert judgment)

2. Inform HRA method development

- Part-validation of PSF weights and thresholds
- How many levels for a PSF (2.gen: Information for emphasis on context)
- Interaction between PSFs
- Variability/Distribution of human performance
- Validation/Benchmark of several methods?

2nd gen / ATHEANA Relevance

- Qualitative insights on context and crew characteristics
- Qualitative insights on plant conditions, deviations from PRA base case scenarios
  - Vulnerabilities in the operator's knowledge base

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3. Input to generic DB/repository for use in quantification

- Quantification of Human Failure Events (generic)
- Put results of success/failure (or continuous analogy) into Bayesian models or other data structures directly?
  - Frequencies of executed actions in specific scenarios
- We can supplement operational data with simulators
  - Looking at a PRA/PSA, we see many unlikely scenarios
  - Instead of waiting for a handful of operational events, we can generate a large quantity of data useful for probability estimates

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HERA input

- Populate HERA with simulator data
- Will increase the use of HERA to inform also on (simulated) accident situations
- Similar for NARA, the successor of HEART

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PSFs from NUREG-1792, Good Practices

1. Training/experience
2. Procedures and administrative controls
3. Instrumentation
4. Time available and time required to complete the act, including the impact of concurrent and competing activities
5. Complexity of the required diagnosis and response, the need for special sequencing, and the familiarity of the situation
6. Workload, Time Pressure, and Stress
7. Team/crew dynamics and crew characteristics
8. Available staffing/resources
9. Human-system interface (HSI)
15. Consideration of "realistic" accident sequence diversions and deviations

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The task complexity experiment 2003/2004

Halden Work Report –758 by
Karin Laumann, Per Øivind Braarud, Håkan Svengren

Per Øivind Braarud

Dec. 2005

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Task Complexity factors for the Crew

- **Time pressure** is about the temporal demand involved in monitoring and operating the process.
  - Urgent need to act on the process, need to respond to the process without much time to diagnose
- **Information load** is about the amount of information needed to identify what to do, to identify a solution, or to monitor the process.
  - Number of systems and sub-systems affected by faults, change in many parts of the process, amount of alarms
- **Masking** is about identifying the cause(s) or the meaning of the process symptoms.
  - Indication of one faults mask indication of other fault, Missing indications, Delayed feedback to confirm system or process state

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Research questions

- How do the complexity factors affect human performance
- Methodological choice:
  - A main task is studied in several scenarios
  - Time pressure, information load and masking are studied by introducing additional tasks expected to create different contexts for the main task
  - To be able to separate the context and the main task across scenario variants.
- Assumptions:
  - Will additional tasks have effect on the main task?
    - What characterise additional tasks with and without effect?
    - What kind of effect will the additional tasks create?

Expected effects of Context Manipulation

- The additional tasks could cause:
  - Time Pressure if some of the available time had to be used on the additional tasks, or if the crew experience the additional task as increased time pressure
  - Information Load if the crews attended to and are distracted by the the additional task, but do not use substantial time on the task.
  - Masking if they make it more difficult to understand the process status and the process development.

Participants

- 7 crews with three licensed operator in each crew participated in the experiment for one week
  - Shift Supervisor
  - Reactor Operator
  - Turbine Operator
- This crew configuration is the normal / regular crew composition at the simulated plants
- The crews came from the simulated plant and from the sister plant of the simulated plant

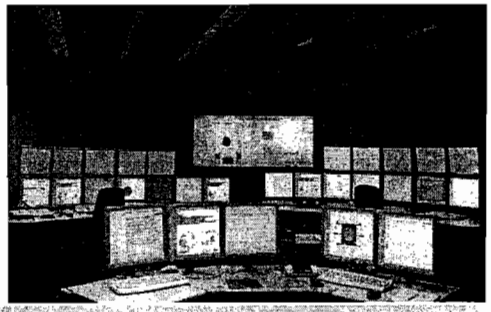
Participant characteristics

Operator	*Mean Age*	*Mean Experience in actual position*
Shift Supervisor	49 years (42-59)	9.5 years (.5-26)
Reactor Operator	44 years (36-51)	7.5 years (3-18)
Turbine Operator	37 years (32-46)	2.5 years (1-6)

Simulator

- HAMMLAB's HAMBO simulator simulates a Swedish BWR nuclear power plant
  - late generation ABB plant
- Full-scale simulator with a computerized human-machine interface

Interface of the simulator in the experiment



Operation Procedures

- The procedures are copies of the simulated plants procedures
- The sister plants EOP differ from the simulated plants EOP
  - Operator from the sister plant use the sister plants EOP
- Four main types of procedures
  - Normal operation, including actions for responding to alarms
  - Normal operation used to bring the plant to different operational states
  - Event based for anticipated events
  - EOP (for beyond design basis accidents)
  - In addition: First check procedure to get a quick overview of the plant when event or accident occur.

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Training in HAMMLAB

- Education and training on all interface functionality
  - For example Navigation, start and stop of objects, trend curves, alarm management
- Some special features, known to need more training and important features, are trained on more thoroughly
  - For example: Symbols that are not normally used in the plants P&ID.
- Inform about scope of the plant simulation.
  - Comparable to a full scope training simulator
- Presentation of the available documentation in the control room
- Test scenario for observing that the crew manage the computerized interface.

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Simulation Set-up

- Scenario run plans and experiment staff procedures to ensure same conditions for each crew
  - For example to secure data collection to avoid re-start of scenario
- Functions performed by experimental staff:
  - Running the simulator, administer the scenario run
  - Giving expert comments during the scenario
  - Observing crew behaviour
  - Recording of video / audio
  - External Control room communications
    - Field operators
    - Safety Engineer on duty
    - Plant Management
    - Other

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Scenarios

5 scenario types, 4 variants of each

Investigating	*Implemented in Scenario*
Time Pressure & Information load (by scenario manipulation)	Incomplete scram/start of the boron system
	Loss of outside power/transfer of bus bars to the 70 kV grid
	Medium LOCA /start of auxiliary feed water pumps
Masking (by scenario manipulation)	Leakage from shut down cooling system
Accident operation further down the event sequence (by observation)	LOCA or LOOP leading to depressurization and low-pressure coolant injection

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Experimental design: Scenario variants

- Context effect studied by the scenario variants
- Within Subject Design: All crews participate in all experimental conditions.
  - Each crew run 5 main scenarios x 4 variants = 20 scenarios
  - 7 crews = 140 runs total

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Exp. Design: Balancing of scenarios

- The order of scenarios for the crews was counter-balanced as much as possible over the 20 scenarios.
- The scenarios were also balanced in such a way that the crews ran only one scenario variant in each of the main scenarios on one day.

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Measures and data collection

- Both the reactor operator and the turbine operator had head-mounted cameras that captured the process displays that they watched
- Two cameras were used that captured the whole control room setting
- All three operators had a small microphone attached that recorded the communication within the control room
- Logging system: Responses on the interface and simulator were logged during the experiment
- Also, a subject-matter expert commented on the crew's work with the scenario while the scenario was running.

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Questionnaires

- Task complexity questionnaire
- Performance Shaping Factors (PSF)-questionnaire
- Observer's evaluation

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Debriefing

- After each scenario had run the crews did a debriefing of the scenario
- The shift supervisor lead the debriefing
- Template to do the debriefing

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Masking

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Masking – studied in one main scenario

- Research Questions:
  - How does the complexity of a second task effect on the performance of a relatively simple main task?
  - What are the performance effects of different levels / types of masking complexity?
  - What characterize the crews operation of the scenarios masking problem?
  - What crew characteristics can be extracted from observing the scenario?
- There is 4 scenario variants. Scenario 1 to 4.
- Main Task and Additional Task
  - Each scenario variant have the same Main Task.
  - Each scenario variant have different version of an Additional Task.

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Main Task

- All 4 scenario variants have a leaking shut down cooling system.
- The leakage actuate the automatic isolation of the system
- The in-board and out-board containment valves in series of one pipe do not close.
  - One of the valves can be closed from the control room. This will isolate the leakage.
- The Main task is an easy task:
  - The task has clear indications: Temperature alarm, Alarm / indication of actuated isolation logic
  - There is guidance in the event procedure to check the containment valves
  - Closing the containment valve is easy from the process format

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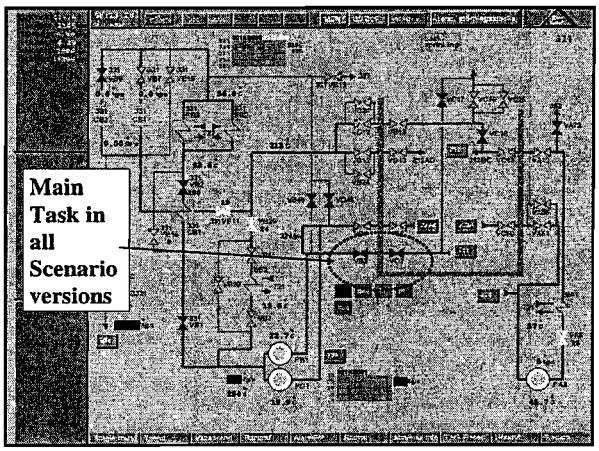
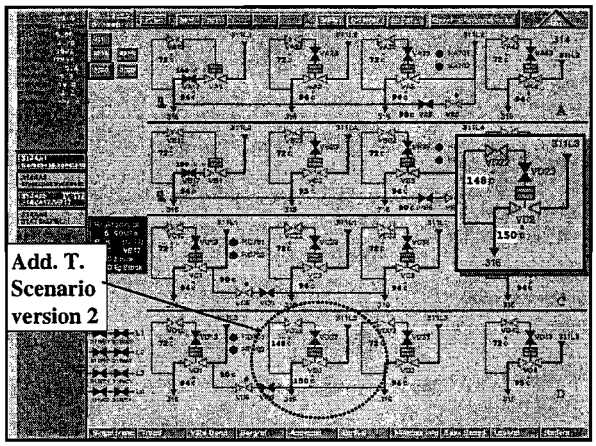
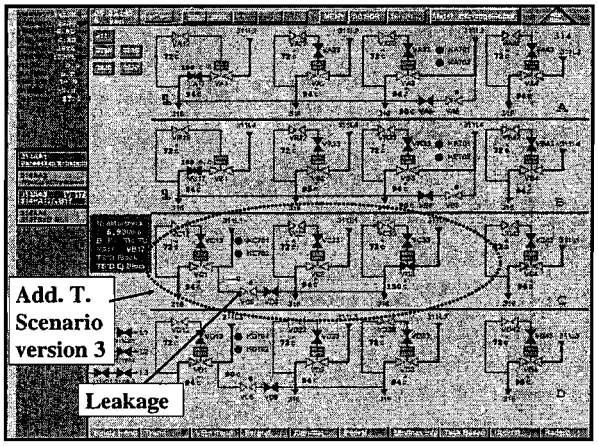
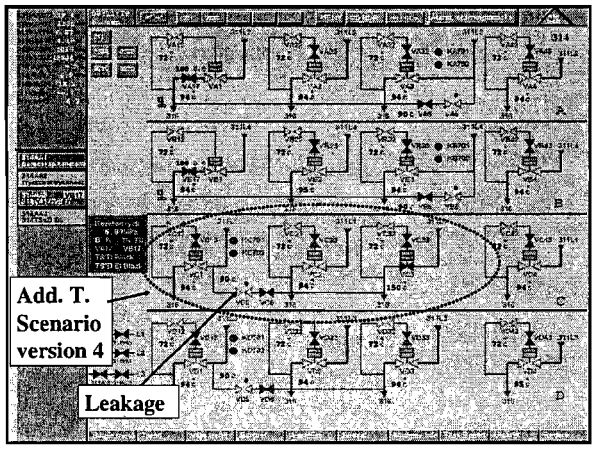
Additional Task

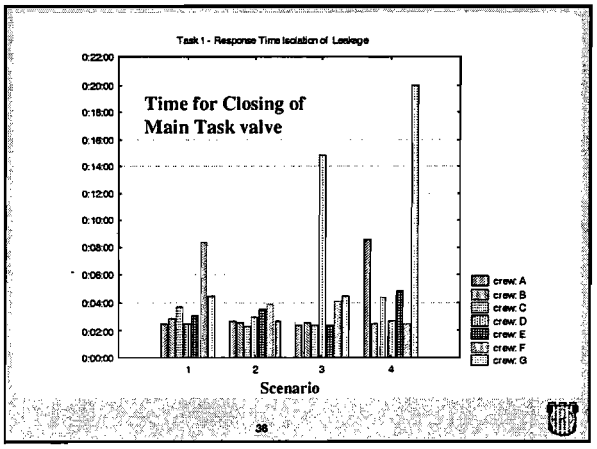
- The four scenario variants have different leakage of the Reactor's Steam Pressure Relief System and different indication of the leakage.
  - Sc1: No Steam Pressure Relief System leakage. Sc 1 contains the Main Task only.
  - Sc2: Steam Pressure Relief System main valve faulty open, without open indication.
  - Sc3: Steam Pressure Relief System leakage through TA valve, indication of main relief valve open, temperature alarm before TA valve.
  - Sc4: Steam Pressure Relief System leakage leakage through TA valve, indication of main relief valve open, *no* temperature alarm before TA valve.

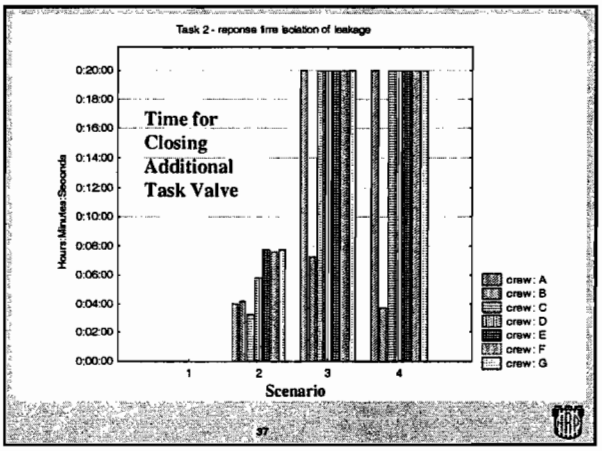


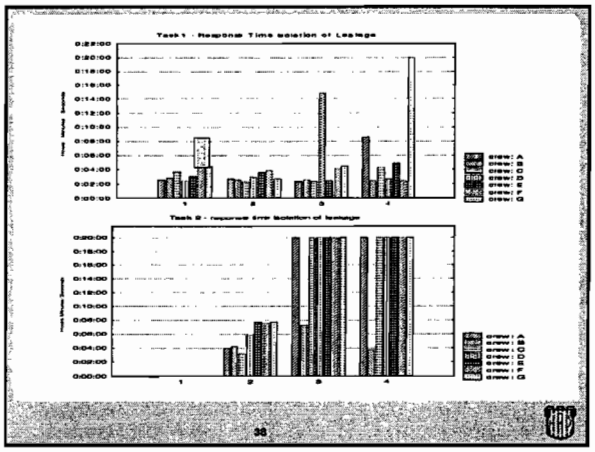












Interpretation

- Comparing the response times across the scenario versions suggest that the long response times for the Main Task is related to the difficulty of the Additional Task.
- 3 runs of Scenario 3 or 4 have long response times. Case Analysis confirms:
  - Crew D Scenario 3 is occupied with the Additional Task. Both SS and RO focus on the additional task.
  - Crew A Scenario 4 is occupied with the Additional Task. Both SS and RO focus on the additional task, while TO got the task of checking the Main Task procedures.
  - Crew G Scenario 4 is occupied with the Additional Task. Both SS and RO focus on the additional task.

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Case analyses – Sc version 2, I

- Scenario variant 2: SPR (Steam Pressure Relief) System main valve without open indication
- All crews start with Main Task leakage before SPR leakage. They have Isolation logic actuated - clear indication.
- Crew A, B, C:
  - Detect SPR leakage by looking at alarms or detecting condenser level decreasing.
  - Decide quickly to give closing order to isolation valve
- Crew D:
  - Detect SPR alarm early, but conclude that SPR valve have been temporarily open, and do not investigate SPR further at this point
  - Later, they have condenser alarm, suspect that SPR valve is actually open, closes SPR valve.

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Case analyses – Sc version 2, II

- Crew E:
  - Detect SPR alarm, conclude that valve is closed but leaking, leave SPR.
  - Later, detect condenser level, and start speculating about SPR open.
- Crew F:
  - Detect SPR alarm, conclude that valve is closed but leaking
  - Give closing order to SPR valve, but it seems like they believe main valve is actually closed.
  - No indication of that the crew really understood that the main valve was fully open for several minutes.
- Crew G:
  - Occupied with the Main Task, and do not detect SPR alarms
  - Misinterpret condenser level related to the main Task leakage (RO and TO).
  - Detect Suppression pool temperature alarm, and suspect SPR leakage (SC)

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Crew Characteristics

- Variability in how the crews interpret a somewhat / little ambiguous process picture.
- The variability in response time of closing the SPR main valve is related to the crews interpretation of the situation
  - Cognition / Diagnosis type of activity

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Case analysis Scenario variant 3

- Crew B (the only crew that solved the additional task in scenario 3)
  - Detect the Main Task leakage, the automatic isolation, and the SPR leakage as expected.
  - SC takes a first overview of the shut down cooling system (Main Task)
    - SC notices that RO is occupied with the SPR leakage.
    - SC closes the faulty Main Task valve
    - Gives time for both RO and SC to look at the SPR problem.
  - RO detects the indication of the masked leakage location
    - SC perform a correct diagnosis of the leakage.
- Crew Characteristics:
  - Team Management: Division of work.
  - Communication: RO communicate in the crew a detection he himself have not interpreted yet,

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Conclusions, Masking scenarios

- Scenario version 2
  - Added task (pressure relief system leakage):
    - 3 crews did immediate correct diagnosis of the open relief valve
    - 4 crews recovered from an initial wrong or incomplete diagnosis
  - Main task (leakage from cooling system shutdown rector):
    - No adverse effect of the added task on any of the seven crews' performance
- Scenarios versions 3 and 4 had more difficult masked tasks
  - Added task:
    - Only 1 crew solved the task in both version 3 and 4
  - Main task
    - 6 of 14 runs where the crew's main task was clearly disturbed by the additional masked task
    - 3 out of those 6 had longer response time of isolating the leakage than a predefined expected performance criteria

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Conclusions: Effect of a secondary task with masked information

- A secondary task has the potential to affect the performance of an easy main task if:
- The secondary task has a salient indication, or the secondary task results in process deviations clearly related to the secondary task and not the first task, simultaneously with the work on the first task. If the secondary task is judged to be important, then it can interfere with the main task.

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Conclusions: Effect of a secondary task with masked information

- There are some complicating properties of the secondary task that attract attention and resources such as
  - Unclear cause and effect: difficulty in seeing the cause for the process indication, actions to solve the task do not give the expected consequences.
  - Strong potential for misdiagnosis: the secondary task has the potential for an obvious initial diagnosis that is actually wrong.
  - Cost of no resolution: if not solving the secondary task has a significant effect on the process development and the process status, the second task will generate more tasks that have the potential to take attention and resources away from the main (first) task.

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Conclusions: Effect of a secondary task with masked information

- There are weaknesses in resource allocation to the secondary task: the secondary task will consume undue resources if there are vulnerabilities in the crew's work processes in terms of division of work between two or more problems, or in keeping division of work between general process overview and working with the solution of given detected tasks.

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Time Pressure and Information Load

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Time Pressure and Information Load

- Research questions
  - How do additional tasks to a main task create time pressure and information load for the crew
  - How do Time pressure and Information Load affect human performance
  - What crew characteristics can be extracted from the scenario runs
- Three main scenarios
- Four variants of each main scenario representing added time pressure and information load.

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Incomplete scram/start of the boron system
Initiating Event

- A failure and a leakage in the Main Feedwater give Low level in the reactor tank, Power reduction, Isolation of main Feedwater and Scram.
- Scram is incomplete. Reactor not under-critical, the average reactor power is higher than 2 percent.
  - 12 adjacent control rods are not inserted (stuck)
  - 18 spread out control rods are not inserted
    - Two scram valves do not open.

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Incomplete scram/start of the boron system
Main Tasks

MAIN TASKS are included in all scenario variants of the Incomplete Scram scenario

- Manual start of the Boron system to bring the reactor to a sub critical state. Procedure exists for this.
- Open scram valve to get more rods into the core. One out two scram valves can be operated, the other one is stuck.
- Put one faulted auxiliary feed water train in operation (Aux feedwater needed due to Main Feedwater Isolation)
  - Close a valve to get the aux train to deliver water

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Incomplete scram/start of the boron system
Additional Tasks

Time Pressure Tasks:
- Main Steam Pressure Relief System Valve open (by fault)
  - Crew need to Close an isolation valve to the main valve
- Auxiliary Feedwater faults:
  - Train A, Electrical failure. Crew need to Order FO / Maintenance.
  - Train D, Faulted automatic start signal to the Aux Feedwater pump and to a pump of Train D cooling system. Can be started manually

Information Load Tasks:
- Feedwater tank level decreasing (indication on the large screen)
- Intermediate cooling system Train B High temperature alarm .
- Reactor recirculation pump High vibrations alarm on. Will appear and disappear frequently.

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Scenario Variants

Scenario Variant	*Tasks*
1. Base Case	Main Tasks only
2. Time Pressure	Main Tasks + Time Pressure Tasks
3. Information Load	Main Tasks + Information Load Tasks
4. Time P. + Info. Load	Main Tasks + Time Pressure Tasks and Information Load Tasks

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Results: Time to start boron system after scram

Scenario Variants	Crew A	Crew B	Crew C	Crew D	Crew E	Crew F	Crew G	Average
4.1	2:45	0:49	3:27	3:59		0:49		3:16
4.2	3:18	1:04	4:27	1:19	3:04	2:01		3:51
4.3	2:27		4:14	1:11	3:18	3:59	3:40	3:26
4.4	2:09	2:28		1:52		4:04		4:37

One standard deviation from mean

More than one 5 minutes which was estimated as nominal time

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Results

Main Task: Start Boron System

Variant	A	B	C	D	E	F	G
1 Base	2:45	0:49	3:27	3:59	5:10	0:49	5:56
2 Time	3:18	1:04	4:27	1:19	3:04	2:01	
3 Info	2:27	5:17	4:14	1:11	3:18	3:59	3:40
4 T+I	2:09	2:28		1:52		4:04	

Additional Task: Steam Pressure Relief Valve

Variant	A	B	C	D	E	F	G
1 Base							
2 Time	2:40	2:07	3:04	2:54	3:02		*
3 Info							
4 T+I		3:17		4:19	3:22		

Additional Task: Auxiliary Feedwater

Variant	A	B	C	D	E	F	G
1 Base							
2 Time	14:14	8:04	11:57	4:49	11:37	2:58	2:10
3 Info							
4 T+I	NO (SF)	5:52	5:01	3:26	1:42		2:48

Case Study: Crew G, Sc variant 2 (Start Boron 11:43)

- Crew firstly detect and work (RO and SS) with getting Aux feedwater working due to the low reactor level. SS informs plant management.
- RO detects and works with open SPR valve. Do not manage to close it.
- 5:30 after Feedwater Isolation, RO detects rods not inserted. SC asks RO to Start Boron system.
- SC and RO discuss if the open Steam pressure Relief valve will boil away the Boron
- RO ask SC to try to close the SPR Valve. SC do not succeed. Crew order FO to close SPR valve.
- RO focus on the need to by-pass filter in reactor clean up system.
- 10:21 SS asks RO to start Boron system

Crew Characteristics

- Crew Characteristics (in response to the scenario):
  - Division of work: Resources "pulled by" the first salient and important task (both SS and RO), to little attention to overview of the situation.
  - Division of work: A task not solved draws resources. Not solved by RO, SS uses resources on the task.

Case Study: Crew F Sc variant 4

- RO starts with Aux Feedw. Have problem with getting train D running.
- SS order RO to work with the Boration, and TO to work with the Aux Feedw. and the open SPR valve.
  - TO have problems with the two reactor tasks.
- Efficient work division for the Boration, which was the most important task, but led to Depressurisation.

Characteristics from case analyses

- Division of work / Resource management:
  - Vulnerability (manifest for some crews) Use undue resources on the salient task and forget the overview of the situation.
  - Crew that performs well have efficient work division. Supervisor perform task if needed, but do not forget to keep overview of the situation.
- Communication decreases in quality for the more difficult scenario variants
- Interaction between scenario complications and crew characteristics
- Dependency / exaggeration of tasks
  - Not solving one task draws additional resources

Incomplete scram/start of the boron system

Information Load

- None of the crews priories to work on the information load alarms rather than the more important task in the scenarios such as start the boron system, start the auxiliary feedwater pump or closing the open pressure relief valve.
- However, information load seemed to be disturbing for the operators.
  - For example several of the information load alarms made the alarm signal go one and off all the time and many of the crews for example continuously kept the alarm stop button pressed in with one hand while they were working on the scenarios

LOOP / Transfer of bus bars to backup grid
Event

- Loss of main Grid (400 kV),
  - This gives "House Turbine" operation.
- The back up grid is available (70 kV)
- Procedures states transfer to backup grid if main grid unavailable in the foreseen future.
  - Manual transfer only
- Turbine condenser have an air leakage that would lead to turbine trip after about 25 minutes.
  - Turbine trip / reactor scram give buses connected to Emergency AC power a automatic sequential start of components.

LOOP / Transfer of bus bars to backup grid
Main Task

- Quick Transfer of buses to the back-up grid
  - To avoid relying on the automatic AC Power System giving stop and restart of components.
  - To avoid that components will be out of power the time it takes for the Emergency AC Power to sequentially feed components.
  - To avoid that components supplied by the ordinary grid being out of power. For example Feedwater pumps.
- Four Trains
  - Difficult to transfer all four trains so that power is continuously supplied to all four Trains
  - There is different arguments for prioritising transfer between the four Trains.

LOOP / Transfer of bus bars to backup grid
Additional Tasks

Time Pressure Task

- Leakage from SPR system (stuck isolation valve). Will increase temperature in condensation pool
  - Manual scram or scram on high temp. in condensation pool.
    - Reduced Time Available for Quick transfer of Bus bars

Information Load Tasks

- Metal Temperature generator bearing Alarm.
- Turbine bearing vibration Alarm
- One channel reactor level (Train C) decreasing
- Three more alarms

LOOP / Transfer of bus bars to backup grid
Results

Crew	Scenario 3.1 (Base case) (Low time pressure and low information load)					Scenario 3.2 (High time pressure)					Scenario 3.3 (High information load)					Scenario 3.4 (High time pressure and high information load)				
	1 Time	2 Op	3 Train	4 hPa	5 sra	1 Time	2 Op	3 Train	4 Degr	5 sra	1 Time	2 Op	3 Train	4 hPa	5 sra	1 Time	2 Op	3 Train	4 Degr	5 sra
A	17:40	TO	D	18.09	Yes	07:46	TO	D	23.09	yes	33:17	TO	D	25.21	yes	06:42	TO	D	23.87	yes
	18:05	TO	A		yes	08:00	TO	C		yes	33:29	TO	B		yes	06:52	TO	C		yes
	18:39	TO	B		no	08:15	TO	B		yes	33:39	TO	A		yes					
B	28:23	SS	D	21.60	No	None					None					09:42	RO	D	27.56	yes
	28:25	TO	B		yes											09:44	TO	B		yes
	28:25	TO	C		yes											10:04	TO	A		yes
	28:54	RO	A		yes											10:04	RO	C		yes
C	28:50	TO	A	21.66	Yes	14:00	TO	A	22.08	yes	07:03	TO	A	9.14	yes	05:23	TO	A	25.31	yes
	29:03	TO	B		Yes	14:11	TO	B		yes	07:27	TO	B		yes	05:37	TO	B		yes
						14:26	TO	C		yes	07:34	TO	C		yes	05:46	TO	C		yes
						15:07	TO	D		no						05:54	TO	D		no
D	05:30	TO	D	3.04	Yes	None					07:24	TO	D	9.48	yes	30:18	TO	D	34.76	no
	34:30	TO	B	24.33	yes						09:24	TO	C	11.40	yes					
	34:40	TO	A		yes						09:41	TO	B		yes					
	34:50	TO	C		no						09:50	TO	A		no					
E	22:30	TO	A	18.96	Yes	09:06	TO	A	27.59	yes	TP	TP	TP	TP	TP	10:48	TO	A	28.84	yes
	22:40	TO	B		yes	09:55	TO	B		yes						11:14	TO	B		yes
	22:45	TO	C		no	10:08	TO	C		yes						11:21	TO	C		yes
F	32:35	SS	D	22.43	Yes	08:25	TO	D	22.23	yes	09:22	TO	A	16.82	yes	11:31	TO	C	29.67	yes
	45:30	TO	A	23.55	Yes	08:47	TO	C		yes	09:30	TO	B		yes	11:55	TO	A		yes
						08:57	TO	B		yes	09:43	TO	C		yes	12:08	TO	B		yes
						09:12	TO	A		no	14:54	TO	D		no					
G	23:10	SS	D	25.51	Yes	10:24	SS	D	28.27	No	20:23	SS	D	16.66	yes	18:35	SS	D	18.35	yes
	23:35	SS	B		yes	10:37	SS	C		yes	20:42	SS	B		yes	18:44	SS	B		yes
	23:50	SS	C		yes	10:43	SS	B		yes	20:52	SS	C		yes	19:06	SS	A		yes
	23:55	SS	A			10:48	SS	A		yes	20:53	SS	A		no					

Results

- Time Pressure effect
  - Four crews actuated scram without performing any transfer of trains to the backup grid.
    - None of these was in the Base case
    - One crew deliberately decided to not transfer any trains to the back up grid.
    - Three crews scrammed the reactor without any communication of considering the transfer to the backup grid.

Results

- Expected Information Load Tasks created Time Pressure
  - Metal Temperature generator bearing Alarm
    - Just passed H1 level, next level H2 indicate manual trip
  - Turbine bearing vibration Alarm
    - Fluctuated around H1 level, next level H2 give trip.
  - Case analyses of the runs in scenario variant 3 (added information load tasks only) showed:
    - crews experienced time pressure to transfer bus bars or to trip turbine due to the generator metal temperature alarm or the turbine vibration alarm (4 out of 7 crews)

Results

- Crews did not use the relatively more time available in the Base Case to plan ahead
  - Prioritised the current problems, checking and surveying the plant
  - Used much time / resources on working with the condenser air leakage
    - Instead of allocating the turbine operator to that problem and allocate RO or SS to plan ahead.

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HRA and PRA implications

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PSFs from NUREG-1792, Good Practices

1. Training/experience
2. Procedures and administrative controls
3. Instrumentation
4. Time available and time required to complete the act, including the impact of concurrent and competing activities
5. Complexity of the required diagnosis and response, the need for special sequencing, and the familiarity of the situation
6. Workload, Time Pressure, and Stress
7. Team/crew dynamics and crew characteristics
8. Available staffing/resources
9. Human-system interface (HSI)
15. Consideration of "realistic" accident sequence diversions and deviations

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2nd gen / ATHEANA Relevance

- Qualitative insights on context and crew characteristics
- Qualitative insights on plant conditions, deviations from PRA base case scenarios
  - Vulnerabilities in the operator's knowledge base
- "Additional" tasks judged to be of safety relevance may occupy crew resources and show effect on the main task, I.e. the HFE relevant task
  - The additional task do not need to be linked to the IE
- Consider the need to include search for tasks that could occur in addition and simultaneously to the PRA defined HFE?
  - E.g. latent additional failures?

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2nd gen / ATHEANA Relevance, cont

- Good communication in the crew and good division of work are important to solve well a scenario with high time pressure.
- The crew's performance in a scenario depends on how difficult the main task is, and the difficulty of the context
  - E.g., how many other important things they have to do simultaneously with the main task
- The crews are normally very good at prioritizing important tasks, but not so good to plan coming actions when they have time pressure.

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Example use for HRA, 1st gen

- 1. Inform HRA practitioners
  - Time available/required, time pressure and complexity PSFs
    - The results help determine PSF categories for similar situations in the given scenarios, "When do I apply *highly complex*, when *moderately complex*?"
    - "When should I rate the situation *Inadequate time*?"
  - Case studies: Team/crew dynamics and crew characteristics
- 2. Inform HRA method development
  - Structure of PSFs, interrelations between them
    - Masking, time pressure and information load as parts of *time available, time pressure* and *complexity* PSFs
  - Adaption of weights
    - Complexity and time pressure

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Summary, HRA data from simulators

Purpose

1. Inform HRA practitioners in the use of HRA methods
2. Inform HRA method development
3. Input to HERA and other generic DB/repository for use in quantification

Method

- Controlled study, manipulation, detailed measures

Next steps

- Document methodology
- Run more studies in 2006
  - PWR: Masking and PSF study
  - BWR: Variants of Medium LOCA, Sustained Workload
- Look into generalization issues
  - Compare identical scenarios on Westinghouse PWR with Korean studies on full-scope training simulator
    - Scenarios developed in Halden
    - Identical procedures, Westinghouse EOP package
  - Get crews from U.S. to participate in simulator studies in Halden (W PWR)

Human Event Repository and Analysis (HERA) Project

Bruce Hallbert, INL
Erasmia Lois, US NRC

Advisory Committee on Reactor Safeguards (ACRS)

Human Factors & Probabilistic Risk Assessment Subcommittees Meeting

Rockville, MD
December 15-16, 2005

Briefing Overview

- Update ACRS on the status of efforts related to data production and system development for the HERA database.
  - Data description and system architecture
  - Data types and efforts to incorporate various kinds of human performance evidence
- Describe efforts to address use of data to estimate likelihood of human failure events (HFEs) and HRA model parameters.
  - Summary of workshop on Bayesian methods
  - Discussion of several promising ideas.
- Feedback sought on current direction and approaches to data production and use of data in HRA.

Background

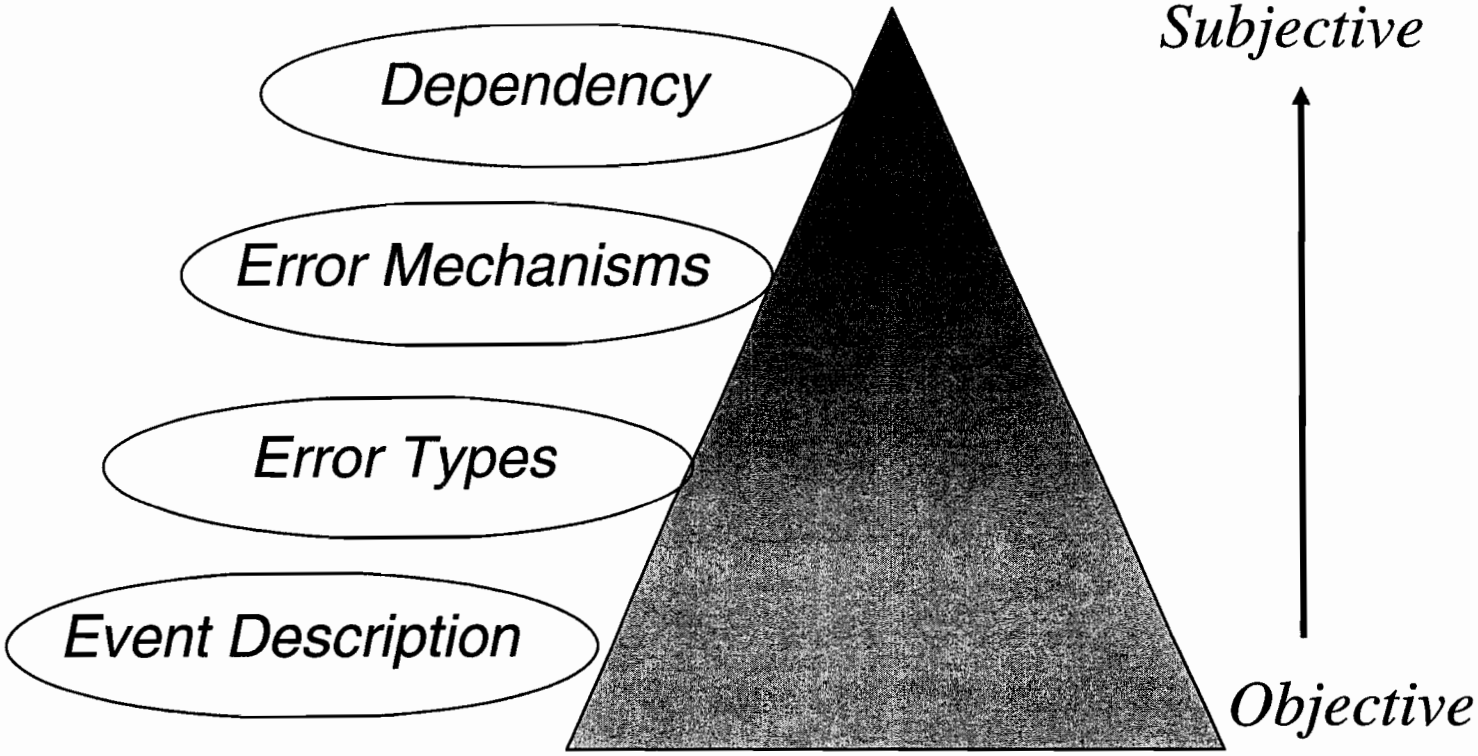
- HRA methods use structured processes to identify potential human failure events and to estimate their likelihood.
- Most methods permit or direct the analyst to account for performance conditions and context.
- Identifying important conditions and accounting for their effects continue to be a challenge for HRA.
- HRA methods may account for different Performance Shaping Factors (PSFs) and may treat them each differently.
- As a result, considerable analyst judgment is required.
- Differences in the magnitude of effect of such factors contribute to the uncertainty in the resultant risk metric.

HERA Objective and Approach

- Objective: Systematic collection of information about human performance in PRA-relevant settings
- Approach:
  - Identify information sources that can be used to inform HRA activities.
  - Develop a formal process for extracting HRA-relevant information.
  - Extract the information/ develop a repository to make information readily available to NRC users.
  - Develop quantification approaches (e.g., Bayesian type methods) to allow the use of various types of evidence in estimations.

Process model

- **Extraction based on concept of layering:**



HERA Main Event Profile

Section I. Plant & Event Overview

1. **Name of Nuclear Plant**
2. **LER #**
3. **Event Type – broken down into 3 types:**
   - **Initiating event**
   - **Condition (Latent)**
   - **Condition (Active)**

Also important in Section I:

- **Date/Time**
- **Mode**
- **Plant Power Level**
- **Potential/ Actual Losses**
- **Components Unavailable**

Plant & Event Overview
Event Types

Initiating Event: **Plant upset condition that leads to shutting down the reactor neutronics process and subsequent removal of decay heat from the reactor core.**

Common Initiating Events include:

- **Reactor trip (TRANS or SCRAM)**
- **Loss of offsite power (LOOP)**
- **Loss of coolant accident (LOCA)**
- **Steam generator tube rupture (SGTR)**
- **Loss of DC bus accident (LDCA)**
- **Loss of service water system (LOSWS), and**
- **Loss of component cooling water (LOCCW)**

Plant & Event Overview
Event Types

Condition: **An event, which, when left unattended, either**

receiving no response from operators or automatically actuated systems would result in an undesired outcome, but that would not require shutting down the reactor neutronics process or removal or decay heat from the reactor core.

2 types of conditions, or off-normal events:

- Active condition: **An off-normal event which occurs as a result of an undesired outcome is an active condition**
- Latent condition: **A latent condition is an off-normal event which has the potential for an undesired outcome, but that outcome doesn't occur at the time the condition is created.**

Section II: Index of Subevents

Main event broken down into subevents

- Subevents coded*
  XHE – Human Error (through unsafe action or inaction)
  HS – Successful Human Action (or recovery)
  XEQ – Equipment Failure
  EQA: Equipment Actuation
  POS: Positive Human Action
  NEG: Negative Human Action

- Subevents – coded consecutively on timeline
  (e.g. XHE1, XHE2, HS1)

*** Subevent codes adapted from SPAR**

Section III: Human Subevent Dependency

Dependency: The means by and extent to which an action or event influences a subsequent action or event. Dependency increases the probability of success or failure of a human action that occurs serially in relation to other actions or events.

- Examples include:
  - Whether subevents involved the same crew or different crews;
  - Whether or not the subevents occurred within a close range of time such that a crew "mindset" or interpretation of the situation might carry over from one event to the next;
  - The procedures and cues used along with the plant conditions related to performing the actions are identical (or nearly so) or related, and the applicable steps in the procedures have few or no other steps in between the applicable steps;
  - Similar PSFs apply to actions;
  - How the actions are performed is similar and they are performed in or near the same location;
  - There is reason to believe that the interpretation of the need for one action might bear on the crew's decision regarding another action, i.e., the basis for one decision in a scenario may influence another decision later in the scenario.

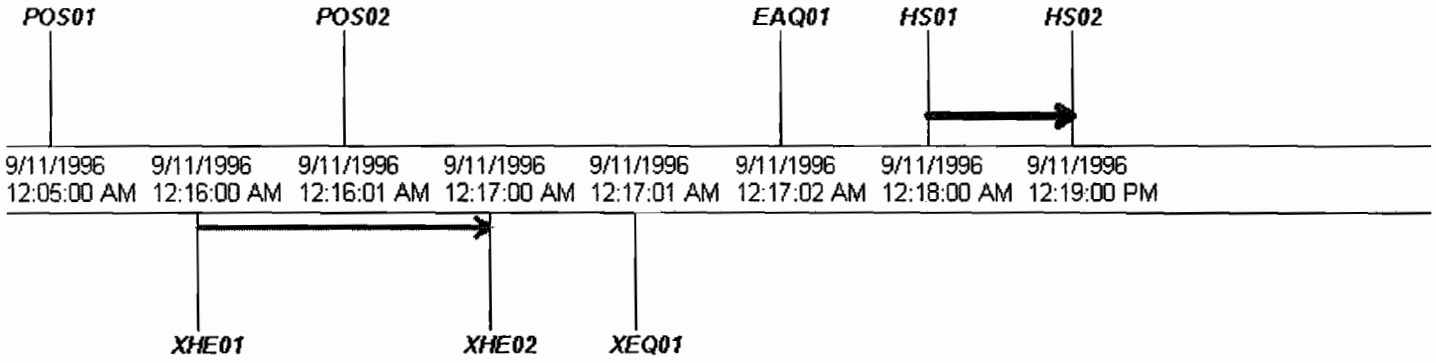
Part B: HERA Subevent Profile

Separate Part B worksheet required for each human subevent :

Each Part B Worksheet broken down into 8 sections:

- **Diagnosis and Planning**
- **Action**
- **Personnel Involved in Subevent**
- **Contributory Plant Factors**
- **Contributory Maintenance Factors**
- **Successful Human Actions**
- **Error Type**
- **Subevent Comments**

Byron Unit 1 (LER 4541996017)



POS01 Operators were preparing to perform a monthly surveillance of the Turbine Protection System

XHE01 Auxiliary Operator (Non-licensed) #2 mistakenly placed the lever actuating tool into position on the TRIP lever, not the TEST lever as he intended.

POS02 AO#2 realized the tool was on the wrong lever

XHE02 AO#2 attempted to remove the lever actuating tool from the TRIP lever reflexively, without taking the time to analyze how best to handle the situation, he rotated the lever enough that is caused a Main Turbine trip.

XEQ01 Main Turbine Trip

EAQ01 Because the reactor was above 30% power, the turbine trip caused an automatic reactor trip, which resulted in actuation of Unit 1 Engineered Safety Features equipment. All automatic safety system actuation occurred as designed.

HS01 Main Control Room entered into Byron Emergency Procedures

HS02 Operators stabilized the unit in Mode 3

Idaho National Laboratory

Status

- 45 LERs form the basis for information in HERA
- ~700 data records (end of FY 05)

Bayesian Methods

Bruce Hallbert, INL
Ali Mosleh, University of Maryland
Erasmia Lois, US NRC

December 14-15, 2005

Background

- Data and observations from experience, research, training & other sources can improve our assessments.
- Improvements needed in making predictions about the kinds of human human performance possible in PRA-relevant contexts.
- Improvements also needed in ability to make predictions about the likelihood of their occurrence.
- Workshop goal and subsequent activities aimed at improving methods for predicting human performance outcomes and likelihood.
- Bayesian methods focus of the workshop.

Presentation Overview

- Three ideas illustrate some promising approaches:
  - Considerations about the nature of the measure(s) we are predicting and ways of combining evidence to facilitate their prediction (Professor Mosleh).
  - Approaches to using human performance research to develop parametrically elaborate, contextually sensitive models (Hallbert).
  - Using operational experience to improve knowledge of HRA model parameters (Professor Mahadevan).

Bayesian Methods and HRA

Ali Mosleh
Center for Risk and Reliability
University of Maryland

Presented to
Advisory Committee on Reactor Safeguards
US Nuclear Regulatory Commission
December 15-16, 2005

BAYESIAN INFERENCE

- The unknown of interest (UOI)
- What we know about the UOI (Prior)
- Other evidence (E)
- Model of the process generating the evidence (Likelihood)
- Combined state of knowledge about the UOI (Posterior)

$$\pi(p|E) = \frac{L(E|p)\pi_0(p)}{\int L(E|p)\pi_0(p)dp}$$

2

UNKNOWN OF INTEREST

Unknowns of Interest

- AO ≡ Operator Response or Action Outcome:
  - Failure
  - Success
- p = Probability (AO = Failure)
- Π (p) ≡ Probability Distribution of p

Questions:

- Why are we uncertain about AO? (why p and not "0" or "1"?)
- Why are we uncertain about p?

3

ESTIMATION FRAMEWORKS

Blue Model

$$P(\text{response}) = \sum_i P(\text{response}|\text{condition } i)P(\text{condition } i)$$

Yellow Model

$$P(\text{response}) = f(\text{PIF})$$

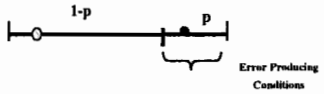
Examples of f:

- Tables (e.g., CREAM)
- Mathematical Function (e.g., SLIM)
- Expert Judgment (e.g., ATHEANA)

4

A POSSIBLE EXPLANATION FOR "p"

- Given a very specific condition (external and internal) the operator response is predictable as either success or failure.
- However in reality we can only specify a class of similar but not identical conditions, a fraction of which lead to failure and the rest result in success. That fraction is "p".
- Therefore "p" is the product of grouping a spectrum of conditions (external and internal) as one context



- The main assumption may be incorrect: Behavior is subject to a "residual randomness" - a source of "p".

5

A POSSIBLE EXPLANATION FOR π(p)

- Variability of p from subclass to subclass (of conditions) within a super-class (e.g., generic context). Examples
  - Stochastic (aleatory) variability in factors, e.g.,
    - in PIFs characterizing the condition (e.g., variability in time pressure due to timing of events)
    - Crew-to-crew characteristics variability
- Uncertainty about the assessed values/states of PIFs for the specific condition or state of interest ("parameter uncertainty")
- Model Uncertainty
  - E.g., incompleteness of PIFs (or factors used to characterize the condition or context) to represent the condition class

6

POSSIBLE AREAS OF APPLICATION OF BAYESIAN METHODS (1/3)

1. Developing **"generic or reference" HEPs** form different types and sources of information

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POSSIBLE AREAS OF APPLICATION OF BAYESIAN METHODS (2/3)

2. Extending **data classification** and event coding frameworks to
   - explicitly capture and record unavoidable use of analyst judgments and interpretations
   - relax the requirements for the quality and quantity of data elements
     - exposure/success data, i.e., the number of opportunities to make a particular type error

8

POSSIBLE AREAS OF APPLICATION OF BAYESIAN METHODS (3/3)

3. Exploring the **role of causal factors** in "forcing" or "influencing" performance
   - Use of Bayesian Belief Network for constructing causal models based on soft evidence
   - Use of evidence to assess probabilities needed in such BBNs.

9

NATURE OF THE EVIDENCE

- Types of evidence available in HRA are often different than conventional statistical evidence. Some of the characteristics of the information are:
- Different forms of information:
  - o Estimates based on data from situations other the error of interest
  - o Expert estimates
  - o HEPs generated by applying HRA Models
- Non-homogenous evidence (different pieces of information from multiple sources)
- Incomplete, indirect, or partially relevant observations

10

FACTORS IN CONSTRUCTING THE LIKELIHOOD FUNCTION

- Type of Information
- Dependence (of information sources)
- Credibility (of data from experts and models)
- Homogeneity (of data points)
- Applicability (to the HEP of interest)
- Evidence Uncertainty
- ...

11

MULTIPLE TYPES OR SOURCES OF INFORMATION

$$\pi(p \mid I_i,\ i=1,2,3,\ldots,n) = \frac{L(I_i,\ i=1,2,3,\ldots,n \mid p)\pi_0(p)}{\int L(I_i,\ i=1,2,3,\ldots,n \mid p)\pi_0(p)dp}$$

$$L(I_i,\ i=1,2,3,\ldots,n \mid p) = \prod_{i=1}^{N} L(I_i \mid p) \qquad \text{(For Independent Types)}$$

Examples of I:

- I_1 = Actual Event Counts
- I_2 = Expert Estimates
- I_3 = Estimates Based on HRA Models

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GENERIC DISTRIBUTION OF "p"

- Evidence: HEP estimates from different sources and reflecting different context or conditions

$$E = \{p_1, p_2, p_3, \ldots, p_n\}$$

1. Assume a beta distribution for p:

$$f(p|\alpha,\beta) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} p^{\alpha-1}(1-p)^{\beta-1}$$

2. Use E to estimate distribution of α and β:

$$\pi(\alpha,\beta|E) = \frac{L(E|\alpha,\beta)\pi_0(\alpha,\beta)}{\int_\alpha\int_\beta L(E|\alpha,\beta)\pi_0(\alpha,\beta)d\alpha d\beta}$$

3. Estimate f(p): $f(p) = \int_\beta\int_\alpha f(p|\alpha,\beta)\pi(\alpha,\beta)d\alpha d\beta$

13

UNCERTAINTY IN DATA ANALYSIS

- Uncertainty in event interpretation
- Partial Failures (quickly recovered error)
- Uncertainty about the success data (error opportunities)
- Uncertainty in cause classification (e.g., PIFs involved and their values /states)
- .....

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DATA UNCERTAINTY: CLASSIFICATION OF CCF EVENT

- ***Impact Vector Method*** and ***Bayesian Estimation*** techniques used to extract information from uncertain and partially relevant data
- **Motivation:** Maximize the use of available information
  - CCF events are often highly system and situation specific
  - Limited in quantity - need to apply data from one situation to another
  - Analysis and classification involve significant judgment

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EXAMPLE CCF EVENT CLASSIFICTION

LER Event Description :		Two of three independent switches failed due to higher than normal levels of fine dust in the environment. Fine dust deposit was also found on the third switch upon inspection.				
Failure Mode:		Fail to Operate				
Common Cause Component Group Size:		3				
Hypotheses for Event						
Hypothesis		Probability	Elements of Impact Vector			
			F_0	F_1	F_2	F_3
1.	Two of three components fail	0.9	0	0	1	0
2.	All three components fail	0.1	0	0	0	1
Average Impact Vector ($\bar{I}$)			$\overline{F_0}$	$\overline{F_1}$	$\overline{F_2}$	$\overline{F_3}$
			0	0	0.9	0.1

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DATA UNCERTAINTY: EXPOSURE DATA

- Exposure or success data are typically unavailable for HEP calculations. In some cases, however, one might be able to develop upper and lower bounds based on auxiliary information.
- Conventional statistical evidence;

$$E = \{N_O \text{ and } N_E\}$$

- Uncertain Evidence

$$UE = \{ f(N_O),\ f(N_E) \}$$

- Bayesian framework allows us to use uncertainty distribution for the exposure/success data (N_O) and number of errors (N_E)

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DEALING WITH UNCERTAIN EVIDENCE

- Weighted Posterior Method

$$\pi(p|UE) = \int \pi(p|E) f(E) dp$$

- Weighted Likelihood Method

$$\pi(p|UE) = \frac{\left[\int L(E|p) f(E)\right]\pi_0(p)}{\int\left[\int L(E|p) f(E)\right]\pi_0(p)dp}$$

- Evidence Averaging Method

$$\pi(p|UE) = \frac{L(\bar{E}|p)\pi_0(p)}{\int L(\bar{E}|p)\pi_0(p)dp}$$

$$\bar{E} = \int E f(E)$$

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MODELING PARTIALLY RELEVANT EVIDENCE

- Totally Relevant

$$\pi(p|E) = \frac{L(E|p)\pi_0(p)}{\int L(E|p)\pi_0(p)dp}$$

- Partially Relevant (one of a number of options)

$$\pi(p|E) = \frac{[L(E|p)]^{\omega}\pi_0(p)}{\int [L(E|p)]^{\omega}\pi_0(p)dp}, \qquad 0 \le \omega \le 1$$

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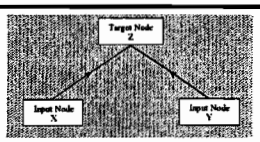
USE OF BBN TO CONSTRUCT CAUSAL MODELS

Bayesian Belief Network (BBN) Basic Concepts



State of X	State of Y	Joint Prob.	Conditional Prob (Z=0)	Unconditional Prob (Z=0)
X=1	Y=1	pq	r_1	r_1 pq
X=0	Y=1	(1-p)q	r_2	r_2 (1-p)q
X=1	Y=0	p(1-q)	r_3	r_3 p(1-q)
X=0	Y=0	(1-p)(1-q)	r_4	r_4 (1-p)(1-q)

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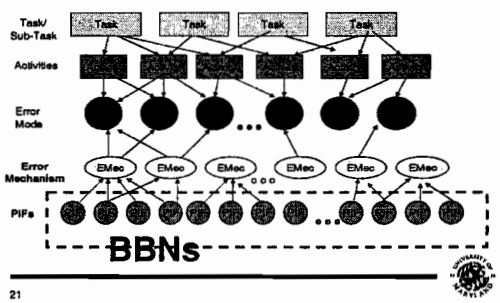
USE OF BBN TO CONSTRUCT A CAUSAL MODEL



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EXAMPLE: IDAC PIF Group Dependencies

Dependent PIF Group / Independent PIF Group		Mental State: Cognitive Mode and Tendencies	Mental State: Emotional Arousal	Mental State: Stress and Feelings	Mental State: Perception and Appraisal	Mental State: Intrinsic Characteristics	Physical Factors	Memorized Information	External Factors: Team-Related Factors	External Factors: Organizational Factors	External Factors: Environmental Factors	External Factors: Conditioning Events & Hidden Faults
Mental State	Cognitive Mode and Tendencies		–	–	–	–	–	(1)*	–	–	–	–
	Emotional Arousal	X		–	–	–	(3)*	(1)*	–	–	–	–
	Stress and Feelings	X	X		–	–	(3)*	–	–	–	–	–
	Perception and Appraisal	X	X	X		–	–	–	–	–	–	–
	Intrinsic Characteristics	X	X	X	X		–	(4)*	(5)*	(5)*	–	–
Physical Factors		X	X	X	X	–		–	–	–	–	–
Memorized Information		–	–	–	X	–	–		–	–	–	–
External Performance Influencing Factors	Team-Related Factors	X	X	X	X	(6)	(6)	(6)		–	–	–
	Organizational Factors	X	X	X	X	(6)	(6)	(6)	–		–	–
	Environmental Factors	–	–	–	–	–	–	–	–	–		–
	Conditioning Events & Hidden Faults	–	–	–	–	–	–	–	–	–	–	

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INFERENCE WITH BBNs

- Forward Inference - Backward Inference

P(Cause x | Error) ⟺ P(Error | Cause x)

- Allows
  - o use of data to estimate causal link conditional probabilities
  - o quantification of HEPs once the network is populated
- Can be used to define a limited number of "generic Contexts" in terms of states of various PIFs

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USE OF DATA (1/2)

- BBN construction:
  - o Test/ Identify BBN Links
- BBN Quantification:
  - o Psychological Literature
  - o Halden data
  - o HERA data
- Modification of generic estimates based on data-based distribution of contexts

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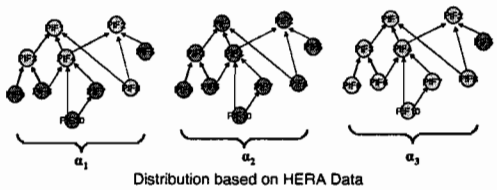
USE OF DATA (1/2)



Distribution based on HERA Data

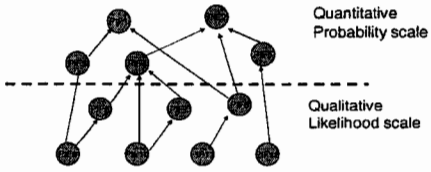
Generic HEP (Q): 10^{-4} — 10^{-2}

Modified HEPs: $Q_i = \alpha_i Q$

ADEQUACY OF BBN

- Pure BBN may be too restrictive
  - o Dynamic factors
  - o Feedback (BBNs are acyclic)
- Quantification is difficult for "inner nodes"
- Quantification requirements can be relaxed using the QQ-BBN Methodology

Qualitative-Quantitative BBN
(Mosleh et al, 2005)



Extending Bayesian Methods: Causal Models and Context in HRA Methods

Bruce P. Hallbert
Idaho National Laboratory

December 15-16, 2005

Bruce.Hallbert@inl.gov (208) 526-9867

Background

- The use of readily available information about human performance in HRA is limited
  - Some HRA methods include data—however, their quality and suitability for HRA analysis is questionable
  - Available sources are not typically used for reasons, such as:
    - HRA is modeling rare events—limited relevant operational data available
    - Thus far, operational experience or other sources have been regarded as not suitable for HRA—do not resemble the conditions analyzed in HRA
- Bayesian methods are used in other fields dealing with rare events (or sparse data) to support/inform their analysis
- Therefore, we believe that the Bayesian framework can be used for HRA as well

Objective

- Objective: improve our capability to incorporate information about human performance from various resources in HRA
- Bayesian –type techniques for incorporating different types of information are available
- Currently we are focusing on developing approaches and associated technical bases that will lead to improvements in Bayesian methods for HRA
  - For example, causal models and context serve as a basis for explaining why people behave certain ways. Linking that to performance prediction is an aim of HRA.
  - An illustration of extending Bayesian methods to explicitly account for causal mechanisms and context will be presented next
- Other frameworks may also be explored in the future

Issue

- Many methods come with causal models identified via models of human performance.
  - Information processing model employed in many methods (e.g., ATHEANA, IDAC, SPAR-H, CREAM, etc.)
- Further acknowledge role of individual history, learning, heuristics, biases, & situational elements that were missing.
  - Error forcing conditions, performance shaping/influencing factors, common performance conditions, etc.
- Quantification entails relating information about specific elements from the performance environment to the model of human behavior to predict the risk metric of interest.

$$P(HFE|S) = \sum_i P(EFE_i|S) * P(UA|EFE_i, S)$$

$$HEP = Nominal_{HEP} * \prod_{i=1}^{n} PSF_i \qquad MFR = MFR_0 * 10^A$$

Approach (cont'd)

- Extending Bayesian methods to employ information about causal and contextual factors can assist in implementing advanced in HRA.
- Need to address:
  - Definition(s) of data and evidence;
  - Use of partial & incomplete evidence;
  - Cases of success and failure;
  - How to employ information about PSFs & context;
  - Identifying & selecting sources of information and methods to derive prior probabilities;
  - Suitability of different distributions (i.e., likelihood functions) and important assumptions they employ;
  - How to extend both the mathematical and conceptual basis in Bayesian methods to be able to employ all of the available evidence.

Research Aims

- Be able to systematically relate elements of environment to performance using models of human performance.
  - Test model assumptions about potential causes;
  - Identify relevant causes and classes of outcomes;
  - Improve the kinds of causal mechanisms that are able to be considered in HRA.
- Improve accuracy of resulting HEP estimates.
  - Account for causal mechanisms with greater fidelity
  - Account for multivariate nature of context
  - Improve our knowledge of uncertainty.
- Develop, test, and employ empirically-based effects models.
  - Similar in concept to limit-state determination for systems
  - Attempt to identify how individual and groups of EFCs interact and dynamically shape performance
- Support validation or benchmarking of HRA methods

Concept Illustration: Operator Performance and PSFs

- Intuitive linkage between PSFs and operator performance.
- Types of PSFs and their effects on error rates vary among HRA methods.
- Assessment of PSFs estimated; uncertainty remains high in most applications.
- Need for better benchmarking and understanding of PSF relationship with performance.
- Linkage needed to build better models of failure.

Purpose

- Explore how data collected in human factors studies could support HRA.
  - Identify a set of PSFs that are predictive of crew performance.
  - Determine the weighting of these factors relative to one another.
  - Demonstrate a general model in which the PSFs can be expressed.
  - Measure the factors affecting the predictive validity of PSFs.
  - Replicate the results and model developments at different plants and at different times.

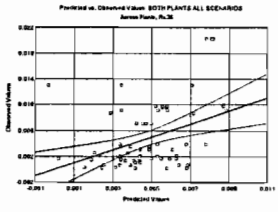
Approach

- Set of 10 PSFs tested for use in predicting crew performance:
  - 7 demonstrated predictive power: Procedures, Training, Stress, Workload, Information Available, System Feedback, HMI.
- Data collection instrument developed to measure "experienced" effects of PSFs.
  - Critical Tasks (mitigation)
  - Simulator trials
  - Rating by operators on the effect of PSFs on performance after scenario.
- Data collected on:
  - 4 crews in U.S. plant (3 Scenarios used: LOFW, SG overfill, SB-LOCA) NUREG/CR-4956
  - 4 crews in Loviisa and 4 crews in HAMMLAB
  - 3 common scenarios: overheating, overcooling, loss of coolant

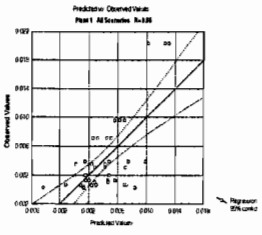
Results

- Linear model with combined PSF weightings
- $Y=a + b_1x_1 + b_2x_2 + ... + b_nx_n$
  - Where Y= critical task mitigation performance
- Sensitive to scenario differences
- Sensitive to plant differences
- Demonstrated predictive ability (critical task performance)

Plant-specific predictive power



All crews, all plants, all scenarios



Plant 1, all scenarios

Summary

- Demonstrated link between performance shaping factors and operator performance.
- Model, technique show promise for explaining variability in task performance
  - Limited to situations in which the defined set of PSFs are, in fact, influencing performance
- Potential use for data collection using plant-specific simulators
  - Time and training demands are small
- No assumptions about strength of relationship between PSFs and performance: empirically established in each data collection trial.
- Potential for reducing uncertainty in HRA.

Additional Thoughts

- Question remains of how to take performance (which we can observe) and predict quantities of interest that we don't.
- Focus attention on sources of data that include successful and unsuccessful performance in challenging contexts.
- Need development of formalisms that are multivariate in nature and allow incorporation of more information.
- Consider how advances in other areas of reliability engineering can help (e.g., BBNs, MCMC, importance sampling, variance reduction techniques, design of experiments, etc.)

Bayesian Analysis of Human Reliability and Performance Shaping Factors

Sankaran Mahadevan
Vanderbilt University

Overview

Quantitative HRA

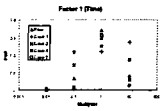
PSF	
Stress	5
Time	10
Complexity	3

SPAR-H model

$$P(E_i \mid A) = \frac{P(A \mid E_i)P(E_i)}{\sum_{i=1}^{n} P(A \mid E_i)P(E_i)}$$

Bayes' Theorem

Update model



Numerical example

Our analysis uses the SPAR-H model

Uses 8 PSFs

- Stress
- Complexity
- Available Time
- Ergonomics
- Experience/Traning
- Fitness for Duty
- Procedures
- Work Processes

Each PSF is a discrete variable with several possible values

The value of each PSF multiplies a nominal error probability

$$P_r = P_0 \prod_{i=1}^{m} F_i$$

Bayes' theorem allows us to combine experience, judgment, and observational data

We are interested in the probability of event E_i

Given:

- Prior estimate of $P(E_i)$, (judgement or experience)
- Occurrence of a related event, A, (observed data)
- Relationship between A and E_i, $P(A \mid E_i)$, (Likelihood)

Likelihood, Prior, Posterior

$$P(E_i \mid A) = \frac{P(A \mid E_i)P(E_i)}{\sum_{i=1}^{n} P(A \mid E_i)P(E_i)}$$

Update performance factor PMFs using human reliability data

Case 1: Data on binomial output

Given:

- Prior PMF estimates, $P(f_1), P(f_2), \ldots, P(f_n)$
- Failure data, k and n

$$\overbrace{P(p_r \mid n,k)}^{\text{Posterior}} \propto \overbrace{P(k,n \mid p_r)}^{\text{Likelihood}} \overbrace{P(p_r)}^{\text{Prior}}$$

Case 1 cont...

Assumptions:

- Each opportunity for human error is independent (trials are independent)
- Performance conditions occur independently (PSFs are independent)

$$P(p_r \mid n,k) \propto P(k,n \mid p_r)P(p_r)$$

$$\binom{n}{k} p_r^k (1-p_r)^{n-k} \qquad \prod_{i=1}^{m} P(f_i)$$

Now have data on failures *and* occurrences of performance factors

Case 2: Data on input and output

Given:

- Prior PMF estimates, $P(f_1), P(f_2), \ldots, P(f_8)$
- Failure data, k and n
- PSF occurrence data, $n_{f1i}, n_{f2i}, \ldots, n_{f8i}$

$$(2)\quad \overbrace{P(p_r \mid n,k)}^{\text{Posterior}} \propto \overbrace{P(k,n \mid p_r)}^{\text{Likelihood}}\,\overbrace{\cancel{P(p_r)}}^{\text{Prior}}$$

$$(1)\quad n_{f1i}, n_{f2i}, \ldots, n_{f8i} \;+\; P(p_r) \;\Rightarrow\; P2(p_r)$$

Correlation between trials can be dealt with by using a generalized binomial distribution

Case 4: Correlated trials

$$P(X=x) = \frac{\binom{n}{x} p^x (1-p)^{n-x} \theta^{x(n-x)}}{f(p,\theta,n)}$$

Generalized binomial distribution (multiplicative form)

$\theta = 1$	Binomial	Independent
$\theta < 1$	Variance greater	Positive correlation
$\theta > 1$	Variance less	Negative correlation

Interpretation of the correlation factor, θ

Estimation of p and θ requires multiple data sets

$(n_1, k_1), (n_2, k_2), (n_3, k_3), \ldots$

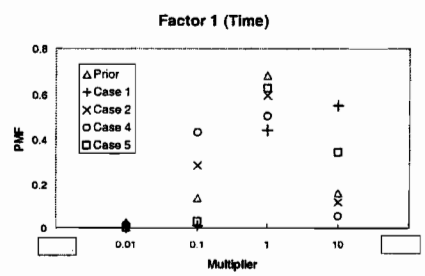
Must simulate the joint PMFs of the correlated factors

Estimate correlation coeff. from data → Generate correlated normals → CDF inverse transformation → Correlated discrete variables

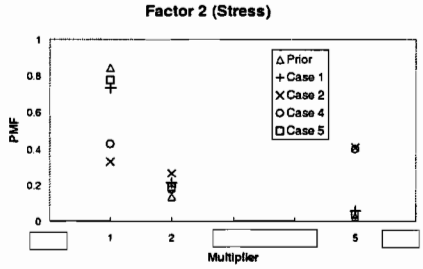
Repeat until desired correlation coeff. is achieved

Since not independent: $\cancel{P(p_r) = \prod_{i=1}^{m} P(f_i)}$

Numerical example results



Numerical example results cont...



Conclusion

www.eurocontrol.int/activities/atc/

Quantitative HRA

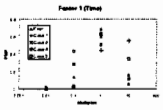
PSF	
Stress	5
Time	10
Complexity	3

SPAR-H model

$$P(E_i \mid A) = \frac{P(A \mid E_i)P(E_i)}{\sum_{i=1}^{n} P(A \mid E_i)P(E_i)}$$

Bayes' Theorem

Update model



Numerical example