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**Results of a Nuclear Power Plant Application of a
New Technique for Human Error Analysis (ATHEANA)¹**

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Abstract

A new method to analyze human errors has been demonstrated at a pressurized water reactor (PWR) nuclear power plant. This was the first application of the new method referred to as A Technique for Human Error Analysis (ATHEANA). The main goals of the demonstration were to test the ATHEANA process as described in the frame-of-reference manual and the implementation guideline, test a training package developed for the method, test the hypothesis that plant operators and trainers have significant insight into the error-forcing-contexts (EFCs) that can make unsafe actions (UAs) more likely, and to identify ways to improve the method and its documentation. A set of criteria to evaluate the "success" of the ATHEANA method as used in the demonstration was identified.

A human reliability analysis (HRA) team was formed that consisted of an expert in probabilistic risk assessment (PRA) with some background in HRA (not ATHEANA) and four personnel from the nuclear power plant. Personnel from the plant included two individuals from their PRA staff and two individuals from their training staff. Both individuals from training are currently licensed operators and one of them was a senior reactor operator "on shift" until a few months before the demonstration.

The demonstration was conducted over a 5 month period and was observed by members of the Nuclear Regulatory Commission's ATHEANA development team, who also served as consultants to the HRA team when necessary. Example results of the demonstration to date, including identified human failure events (HFEs), UAs, and EFCs are discussed. Also addressed is how simulator exercises are used in the ATHEANA demonstration project.

Introduction

Over the past several years the U.S. Nuclear Regulatory Commission (NRC) has sponsored the development of a new method for performing human reliability analyses (HRA). A major impetus for the program was the need for a method that would not only address errors of omission (EOOs), but also errors of commission (EOCs). Both Sandia National Laboratories (SNL) and Brookhaven National Laboratory (BNL) have participated in the development of the new method, referred to as A Technique for Human Error Analysis (ATHEANA). Although several documents have been issued describing the basis and development of ATHEANA [e.g., 1,2,3], two documents currently in draft form will ultimately provide the necessary documentation for applying the method. They include the frame-of-reference manual, which serves as the technical basis document for the method, and the implementation guideline, which provides step-by-step guidance for applying the method. Together, the two documents provide the information needed to identify, characterize, quantify, and integrate into probabilistic risk assessment (PRA) models, potential human failure events (HFEs), unsafe actions (UAs), and their error-forcing contexts (EFCs). HFEs, UAs, and EFCs are defined as follows:

- HFE - A basic event that is modeled in the logic models of a PRA (event and fault trees), and that represents a failure of a function, system, or component that is the result of one or more unsafe

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actions. An HFE reflects the PRA systems' modeling perspective.

- UA - Actions inappropriately taken, or not taken when needed, by plant personnel that result in a degraded plant safety condition.
- EFC - The situation that arises when particular combinations of performance-shaping factors (PSFs) and plant conditions create an environment in which unsafe actions are more likely to occur.

With the completion of the draft FOR manual in early 1997 and the draft IG in April 1997, along with several "step-throughs" of the process by the development team, it was decided that the method was ready for a third party test. Thus, a demonstration of the method was planned for July 1997.

The main goals of the demonstration were to test the ATHEANA process as described in the FOR manual and the IG, test a training package developed for the method, test the hypothesis that plant operators and trainers have significant insight into the EFCs that can make UAs more likely, and to identify ways to improve the method and its documentation. A set of criteria to evaluate the "success" of the ATHEANA method and the demonstration was identified as follows:

1. FOR manual and IG "Work"

- Documentation is understandable
- Process is usable

2. Training is effective

- Motivates team
- Facilitates use of the FOR manual and IG
- Enables leader to direct team
- Results in plant team applying useful retrospective analysis

3. Process identifies risk-significant, demanding scenarios involving errors of commission

- Plant operators judge the scenarios to be "demanding"
- Plant PRA experts judge the scenarios to be "risk significant"
- Plant identifies and implements fixes for some scenarios
- Plant believes that ATHEANA can or will identify important problems

4. Users identify improvements in ATHEANA tools and processes

Seabrook Nuclear Station Demonstration Project

The first demonstration of ATHEANA began at the Seabrook Nuclear Station on July 14, 1997, with a 3-day training session provided by the ATHEANA development team, followed by the beginning of the application of the method. The licensee supported the analysis with two individuals from their PRA staff and two from their training staff. Both individuals from training were currently licensed operators and one of them was a senior reactor operator (SRO) "on shift" until a few months prior to the beginning of the demonstration. A PRA expert, with experience in HRA (not ATHEANA), from SNL served as the team leader for the demonstration. Consulting and documentation support on the application of the method was provided by current members of the ATHEANA development team.

The demonstration was scheduled to proceed over a 20-week period, with most of the actual analysis occurring during six team meetings held at Seabrook. The results and status of the current plan are summarized in Table 1.

As indicated in Table 1, simulator exercises are an important step in the ATHEANA demonstration. They were used in the ATHEANA demonstration to assess the response of actual operating crews to identified EFCs. The goal was not only to see if certain HFEs actually occurred, but also to be able to discuss with operators their perceptions of the scenario, even if they were successful in responding to the initiating event. Even though some crews may handle the situation, their sense of how the EFCs might effect other crews could be relevant to the quantification of the potential

Table 1
Current Plan, Results, and Status of Seabrook ATHEANA Demonstration

Current Plan	Results	Status
Step 1: Set priorities among initiating events (IEs) based on criteria such as licensees interest or concerns regarding potential problems, IE frequency, time to CD, etc.	Top three IEs: 1. Medium loss-of-coolant accident (MLOCA) 2. Loss-of-offsite power (LOSP) - station blackout (SBO) 3. Transient (followed by anticipated transient without scram (ATWS) under special conditions)	Completed
Step 2: Using guidance from FOR manual and IG, identify possible HFEs and associated UAs for functions identified in scenarios.	MLOCA (3 critical functions) • Makeup - 6 HFEs identified • Heat removal - 6 HFES identified • Long-term heat removal -5 HFES LOSP - SBO (3 critical functions) • Heat Removal - 5 HFEs identified • Support (Diesel generators (DGs) and/or cooling to DGs) - 5 HFES • Depressurization (manual) - 6 HFES identified	Completed for MLOCA and LOSP-SBO scenarios ATWS - Pending
Step 3: Identify/derive potential EFCs that could lead to identified UAs	See discussion of interesting scenarios below.	Partially completed for MLOCA sequences. LOSP-SBO and ATWS - Pending
Step 4: Conduct simulator exercises to evaluate impact of reasonable EFCs on UAs (includes information from debriefing of operators)	--	MLOCA scenario scheduled for week of October 6, 1997. LOSP-SBO scenarios planned for week of November 3, 1997.
Step 5: Quantification of EFCs and HFEs	--	Planned for early November 1997
Step 6: Document demonstration and submit method and results of demonstration for peer review	--	Peer review scheduled tentatively for February 1998

HFEs, given the EFCs. The use of the simulator runs also provides an opportunity see what other aspects of the simulated scenario may affect operator performance and to obtain ideas from the operating crews about nonsimulated EFCs that might influence their performance.

Findings and Conclusions

Process. At this stage of the analysis, it appears that the ATHEANA process is working well. The IG's search process and the FOR manual's guidance tables, theoretical discussions, and summary of operating experience are providing a means for nuclear power plant licensees and others to identify potential HFEs, UAs, and EFCs. Through application of the method, interesting scenarios (described in more detail in next section) are being identified and plant personnel on the HRA team are learning to think about and examine potential human errors in different ways. In applying the method, however, the HRA team found several areas where the process documentation and working tools could be improved. We have found that additional guidance must be provided for the search for EFCs and that the tables developed to document and provide a paper trace of the analysis can be improved. In addition, we have come to realize that the training for application of the method must have later modules for EFC search and quantification. Finally, it was found that while the process can be fairly time-consuming the first time through when the analysts are just beginning to understand the method, the analysis rate improves with practice.

A very interesting benefit of the process is that it has helped plant personnel identify safety-related weaknesses in plant barriers and design. Specifically, the MLOCA scenario they developed has led to an unexpected sequence of events that might lead to confusion when using the existing emergency procedures. The EFC development work has suggested ways to improve performance in difficult areas. It appears that one of the trainers will suggest a procedural change to avoid the potential difficulties. In addition, he has decided that inclusion of a version of this scenario in the training sequence next year would be a good idea and is working to that end.

Most Interesting Scenarios.

As presented in Table 1, the ATHEANA process has been used to develop EFCs for the MLOCA and LOSP-SBO initiators/sequences while the EFCs for the ATWS sequence have yet to be developed. As an example of the results from an application of the ATHEANA process, the following information describing the EFCs associated with the MLOCA initiator/sequence is provided.

The MLOCA sequence constructed during the application of the ATHEANA process consists of the initiating event, two HFEs (with one specific UA analyzed for each HFE), and various other "failures" that provide error-forcing contexts. The two HFEs result in loss of makeup and failure of long-term heat removal, and ultimately lead to core damage. The following descriptions provide insight into the sequence as developed by the ATHEANA process.

- MLOCA - The medium LOCA initiating event in and of itself may pose a problem to the operators since they do not generally receive training on this size LOCA and thus are less familiar with the postulated plant conditions and their impact on stepping through the emergency response procedures.
- HFEs
 - Inappropriate termination of makeup: The UA analyzed for this HFE is "Operators stop pump." The specific EFC associated with this HFE/UA deals with the failure of wide-range reactor coolant system (RCS) pressure indications in such a manner that the operators may be led to believe that RCS pressure is higher than it actually is. With this potentially misleading information, along with other accurate information, the operators may elect to terminate injection as allowed by specific steps within the emergency response procedures. For this UA to ultimately lead to a functional failure, the operators would have to continue to believe that termination of makeup is the appropriate action.
 - Inappropriate depletion of resources: For this HFE, the UA is "Operators operate pump outside design parameters." The specific EFC involves the failure to receive an "Empty" reactor water storage tank alarm. Since the operators are directed by procedure to stop pumps that take suction from

the reactor water storage tank upon receipt of an "Empty" alarm, the failure to receive this alarm may delay operator action long enough for the pumps to be damaged due to inadequate suction head requirements. Given the nature of the postulated pump failure, the operator would have little time to correct the effects of the UA.

Other "failures" that will not necessarily lead to core damage but which have the potential to cause the operators problems as they deal with the event include:

- A LOCA-induced steam generator tube leak,
- A turbine-driven emergency feedwater pump trip on overspeed that can be restored, and
- A diesel generator failure that is recoverable.

The main effects from these failures are to reduce the operators' cognitive resources as they deal with the accident scenario and cause support staff to respond to and correct failures that by themselves would not lead to core damage.

Evaluation Against Success Criteria. As noted above, at this stage of the Seabrook demonstration project the ATHEANA process seems to be working well. To illustrate how the demonstration is proceeding, Table 2 presents an evaluation of the ATHEANA method and the demonstration against the success criteria. Additional information regarding progress on the demonstration should be available for the presentation coinciding with this paper.

Table 2.
Evaluation of the Demonstration of ATHEANA Against the Success Criteria

Criterion	Evaluation
Do the FOR manual & IG work?	Self-evaluation: While improvements should be made in some of the guidance and support information contained in the FOR manual and IG and in the process documentation tables, the basic search process for HFEs, UAs, and EFCs appears to be working well. While we have not yet reached the quantification stage, it at least appears that the EFCs being identified are reasonable and in principle quantifiable.
Was the training effective?	Utility evaluation: Initial comments (immediately after training) from the Seabrook personnel who participated in the training were very positive about the overall training package. Some important suggestions for improvements included a more extensive initial overview of the method directed at plant management and a brief review of PRA for the benefit of trainers and operators who need a refresher. It was also suggested that detailed training for later steps in the process, such as quantification, be presented just prior to the beginning of that step.

Criterion	Evaluation
<p>Did the process identify significant scenarios?</p> <ol style="list-style-type: none"> 1. Operators judge them as cognitively demanding? 2. PRA team judge as risk significant? 3. Did plant changes result? 4. Plant believes ATHEANA can identify important scenarios <p>Did the users suggest improvements in the ATHEANA process and tools?</p>	<ul style="list-style-type: none"> • Operators on the team thought so. Tests on current operating crews scheduled for October and November. • Yes • Procedure changes are planned and it is clear that the method will allow plant personnel to consider their procedures from a useful new perspective. • Will be evaluated after completion of the demonstration <p>Yes. For example, the team indicated that the tables in the FOR manual used to guide the identification of EFCs, could be tied together in a clearer and more systematic way. In addition, they also indicated that some aspects of the search process for EFCs in the IG could be improved by more directly tying the description of the process to the use of the tables in the FOR manual.</p>

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