A Description of the Revised ATHEANA (A Technique for Human Event Analysis) [1]

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Abstract

This paper describes the most recent version of a human reliability analysis (HRA) method called "A Technique for Human Event Analysis" (ATHEANA). The new version is documented in NUREG-1624, Rev. 1 [1] and reflects improvements to the method based on comments received from a peer review that was held in 1998 (see [2] for a detailed discussion of the peer review comments) and on the results of an initial trial application of the method conducted at a nuclear power plant in 1997(see Appendix A in [3]). A summary of the more important recommendations resulting from the peer review and trial application is provided and critical and unique aspects of the revised method are discussed.

1. Introduction

The purpose of ATHEANA is to provide an HRA modeling process that can accommodate and represent the human performance found in real nuclear power plant (NPP) events, and that can be used with probabilistic risk assessments (PRAs) or other safety perspectives to resolve safety questions. On the basis of observations of serious events in the operating history of the commercial nuclear power industry, as well as experience in other technologically complex industries,

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the underlying premise of ATHEANA is that significant human errors occur as a result of a combination of influences. Critical influences include the plant conditions and certain human-centered factors that trigger error mechanisms (e.g., biases, heuristics, and processing limitations) in the plant personnel. Given this perspective on the causes of inappropriate actions, a process is needed that can search for likely opportunities for inappropriately triggered mechanisms to cause unsafe actions. The starting point for this search is a framework (see [1]) that represents the interrelationships among error mechanisms, the plant conditions and performance-shaping factors (PSFs) that set them up (the error-forcing context [EFC]), and the consequences of the error mechanisms in terms of how the plant can be rendered less safe. The ATHEANA framework incorporates elements from plant operations and engineering, PRAs, human factors engineering, and behavioral sciences. All of these elements contribute to the understanding of human reliability and its associated influences, and have emerged from the review of significant operational events at NPPs by a multidisciplinary project team representing all of these disciplines.

An initial version of ATHEANA [3] strove to achieve the purpose described above using the ATHEANA framework along with an associated search process designed to identify potential unsafe human actions and their EFCs. The method also provided guidance for quantifying the identified unsafe actions and their PRA associated counterparts, the human failure events (HFEs). Participants in a peer review [2] of that version of the method agreed that ATHEANA represented a significant improvement in HRA methodology, particularly in terms of its unique emphasis on systematically searching for EFCs that could lead operators to take unsafe actions. However, the results of the peer review and the results from a trial application of the method at a nuclear power plant (see Appendix A in [3]), also identified several limitations in the method. Some of the more important limitations included :

- An inadequate specification of the relationship between the plant conditions, PSFs, and human error mechanisms and inadequate guidance for tying these elements together during the search for unsafe actions and EFCs
- An inadequate specification of the characteristics of scenarios that can cause operators problems
- Insufficient guidance for identifying potentially problematic scenarios and unsafe actions, i.e., too many places where "and then a miracle has to occur"

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- A complex and resource intensive application process (at least in part due to inadequate guidance)
- Insufficient guidance for quantification
- No explicit way of encompassing management and organization (M&O) factors or team characteristics
- Limited explicit guidance for performing a retrospective analysis of existing events from the ATHEANA perspective.

Given the ATHEANA search process as it existed at the time, it was realized that the first four limitations noted above are ultimately related and that significant changes in the ATHEANA search process and its associated guidance would be required to address the limitations. The basis and nature of the processes developed to address these limitations are described in the next two sections. While explicit guidance for performing a retrospective analysis of existing events is provided in the revised version of ATHEANA, these revisions will not be addressed in this paper. To date, few improvements to the quantification process have been made and the inclusion of M&O factors and team characteristics has not been significantly addressed. Thus, these issues are not discussed.

2. Deviation Analysis and Search Processes

Our review of operating events, particularly those that seem to have the potential for serious degradations of safety, has shown that these events involve various types of deviations that cause significant challenges to the operators. Examples include:

- Physical deviations where the plant behaves differently than is typically expected and which affect the way the plant behaves compared with the operator's training and expectations.
- Temporal deviations where the time scales of the plant conditions are different from those typically assumed and which may affect the time scales in which operators must act.
- Deviations in the causes of initiating events, in which partial equipment failures or failures in support systems occur, thus creating complex sets of unexpected symptoms that may lead operators to act inappropriately or to delay taking action.

- Deviations associated with failures in instrumentation systems, which can make it difficult for operators to understand and plan suitable responses.

In many cases, these types of deviations can lead operators to fail because of some kind of "mismatch." For example, when a plant behaves in a way that is significantly different from the operators' expectations (a mismatch between plant behavior and training), and the operators respond in accordance with their expectations, the resultant actions can lead to loss of important equipment and functions for the conditions actually taking place. The idea of a "mismatch" has proved a useful concept for describing several kinds of problems underlying events, and provided one basis for revising the ATHEANA search process. In the revised process, the concept of mismatches is used to provide a basis for four specific types of searches for challenging conditions:

- Searches that use keywords to prompt the analysts to consider types of physical deviations from the standard, or base case, accident conditions (for example; larger, smaller, faster, slower).
- Searches that examine the key decision points in related procedures to see if deviations from the base case scenario could lead to inappropriate actions (this is similar in concept to the approach developed by Julius, et al. [4] for full-power applications, though their focus was to identify instrumentation errors that could induce inappropriate actions).
- Searches for possible dependencies between equipment faults and support system failures.
- Searches that try to identify other causes of deviations beyond those listed above. This is an attempt at accomplishing relative "completeness." ATHEANA provides tables and structures to help the analyst think of causes of EFCs beyond those listed here.

The identification of important mismatches and associated EFCs is largely based on an understanding of the kinds of psychological mechanisms causing human errors that can be "set up" by particular plant conditions. The next section briefly discusses these mechanisms and the way ATHEANA identifies their likely effect on operator behavior, thus more clearly specifying the relationship between plant conditions, PSFs, and human error mechanisms.

3. Modeling of Human Error Mechanisms

Accident scenario characteristics, as represented by the behavior of critical parameters, can elicit or interact with certain human responses (e.g., complacency or anxiety) that facilitate the occurrence of an unsafe action or create situations that make certain processing mechanisms, strategies, or biases (e.g., recency effects, confirmation bias, and fixation) inappropriate or ineffective. The "behavior of the parameters" includes the behavior of individual parameters as perceived by the operators, the behavior of the parameters relative to one another, and the more global or "Gestalt" behavior of the parameters as perceived or interpreted by the operators. Furthermore, the behavior of critical parameters can have different impacts, depending on the stage of information processing in which an individual is engaged, i.e., detection, situation assessment, response planning, or response implementation. Moreover, the PSFs that will contribute to the likelihood of an unsafe action occurring will be tied to the specific behavior of the plant and its impact on the operators.

A number of aspects regarding the behavior of parameters in an accident scenario have been identified as potentially influencing the likelihood of certain error mechanisms becoming operative and thereby contributing to an unsafe action. The first set of identified aspects is based on an extension of the "guide words" and concepts used in HAZOP [5] analyses, e.g., a low or higher rate of change in a parameter or a lower or higher than expected value of a parameter. A second set is based on a set of characteristics catalogued by Woods, Roth, Mumaw, and their colleagues [e.g., 6-7] that attempts to describe why problem scenarios are difficult, e.g., scenarios that require unexpected late changes or that contain "red herrings." The basic notion is that scenarios contain features that create the opportunity for normal human information processing and action to be inappropriate or ineffective, essentially by creating unusual cognitive demands.

Whether such behavior in critical parameters or scenarios will affect human information processing depends on such things as the operators' physiological responses to the situation, their current situation model, their expectations regarding what is occurring, the availability of other sources of information, and other PSFs that could be relevant to the scenario. Nevertheless, the way the parameters behave (as represented by plant indicators) and the way the scenario evolves has the potential to elicit certain error mechanisms that lead to unsafe actions. Explicit guidance is provided in the revised method [1] for examining the potential influences of such variations in parameters and scenarios in the context of the different information processing stages, likely error mechanisms, and contributing PSFs.

4. Conclusion

Taken together the revisions to ATHEANA described above address the critical limitations identified as a result of the peer review and test application of ATHEANA. The revisions 1) improve the specification of the relationship between the plant conditions, PSFs, and human error mechanisms, 2) more clearly identify the characteristics of scenarios that can cause operators problems, 3) provide more detailed guidance for identifying potentially problematic scenarios and potential unsafe actions, and 4) through better guidance, reduce the complexity and resource requirements of the application process.

5. References

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