

**Discussion of Comments from a Peer Review of  
A Technique for Human Event Analysis (ATHEANA)<sup>1</sup>**

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**Abstract**

In May of 1998, a technical basis and implementation guidelines document for A Technique for Human Event Analysis (ATHEANA) was issued as a draft report for public comment (NUREG-1624 [Ref. 1]). In conjunction with the release of draft NUREG-1624, a peer review of the new human reliability analysis (HRA) method, its documentation, and the results of an initial test of the method was held over a two-day period in June 1998 in Seattle, Washington. Four internationally known and respected experts in HRA or probabilistic risk assessment were selected to serve as the peer reviewers. In addition, approximately 20 other individuals with an interest in HRA and ATHEANA also attended the peer review and were invited to provide comments. The peer review team was asked to comment on any aspect of the method or the report in which improvements could be made and to discuss its strengths and weaknesses. They were asked to focus on two major aspects: 1) Are the basic premises of ATHEANA on solid ground and is the conceptual basis adequate? 2) Is the ATHEANA implementation process adequate given the description of the intended users in the documentation? The four peer reviewers asked questions and provided oral comments during the peer review meeting and provided written comments approximately two weeks after the completion of the meeting. This paper discusses their major comments.

**Introduction**

In May 1998, a technical basis and implementation guidelines document for A Technique for Human Event Analysis (ATHEANA) was issued as a draft report for public comment (NUREG-1624 [Ref. 1]). In conjunction with the release of draft NUREG-1624, a peer review of the new human reliability analysis (HRA) method, its documentation, and the results of an initial test of the method was held over a two-day period in June 1998 in Seattle, Washington. Four internationally known and respected experts in HRA served as the peer reviewers. A brief description of the reviewers and their credentials follows:

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- Dr. Eric Hollnagel - An internationally recognized specialist in the fields of human reliability analysis, cognitive ergonomics, cognitive systems engineering, and the design and evaluation of man-machine systems. Dr. Hollnagel is the author of more than 230 publications, including six books, articles from recognized journals, conference papers, and reports. In January 1998, he published a book entitled *Cognitive Reliability and Error Analysis Method (CREAM)*, which is itself a new HRA method. He is a member of the Swedish Reactor Safety Council and president of the European Association of Cognitive Ergonomics. Since 1995 Dr. Hollnagel has been principal advisor at the Organization for Economic Cooperation and Development (OECD) Halden Reactor Project, and since 1997 adjunct professor of Human-Machine Interaction at Linköping University, Sweden. He has a Ph.D. in cognitive psychology from the University of Aarhus, Denmark.
- Dr. Pietro Carlo Cacciabue - A sector head at the European Commission, Joint Research Centre, Institute for Systems, Informatics, and Safety, in Ispra, Italy. He has published more than 100 papers in professional journals and conferences and is the editor of a number of conference proceedings and books on safety assessment and human factors. Dr. Cacciabue serves as liaison for and holds a number of positions in several international organizations, such as: the International Association for Probabilistic Safety Assessment and Management (director since 1993), consultant for the Direction Générale Aviation Civile, France (since 1994), Institution of Nuclear Engineers, UK, (member since 1984), European Safety Reliability and Data Assoc. (executive committee member 1992-1995), and the European Association of Aviation Psychology (member from 1996 to the present). He has a Ph.D. in nuclear engineering from Politecnico di Milano, Milan, Italy.
- Dr. Oliver Straeter - A researcher for Gesellschaft für Anlagen und Reaktorsicherheit (GRS) in Germany in the Safety Analysis and Operational Experience Branch. He was a researcher at the RWTH in Aachen and the Ruhruniversität in Bochum and also worked at Siemens Nixdorf AG compiler laboratory in Munich. Dr. Straeter has published several journal articles in the area of human reliability, including a recent article in *Reliability Engineering and System Safety* (Vol 58, 1997), entitled "Human-Centered Modeling in Human Reliability Analysis: Some Trends Based on Case Studies." Dr. Straeter holds a Ph.D. in human engineering psychology from Technical University of Munich.
- Mr. Stuart R. Lewis - A consultant specializing in the application of reliability and quantitative risk analysis methods. Mr. Lewis is the president of Safety and Reliability Optimization Services (SAROS), Inc., Knoxville, TN, which he co-founded in 1984. Examples of current and past relevant work include assisting nuclear licensees in updating and maintaining their probabilistic safety assessments (PSAs) and updating the HRAs for the PSAs of several licensees. He has also assisted the Oak Ridge National Laboratory by reviewing analyses performed under its Accident Sequence Precursor Program, and is assisting Electricité de France in keeping abreast of technical and regulatory developments concerning severe accidents. He performed the HRA portion of several of the probabilistic risk assessments (PRAs) performed by nuclear power plant licensees for the U.S. Nuclear Regulatory Commission's Individual Plant Examination program. Mr. Lewis holds both B.S. and M.S. degrees in nuclear engineering from Purdue University.

In addition, approximately 20 other individuals with an interest in HRA and ATHEANA also attended the peer review meeting and were invited to provide comments. The peer review team was asked to comment on any aspect of the method or the report in which improvements could be made and to discuss its strengths and weaknesses. They were asked to focus on two major aspects:

- (1) The soundness of the philosophy underlying ATHEANA. Are the basic premises on solid ground and is the conceptual basis adequate?
- (2) Is the ATHEANA implementation process adequate, given the description of the intended users in the documentation? Assuming the technical basis is adequate, is the guidance for conducting the search and quantification processes and for integrating the results into the PRA adequate, for example, clear, effective, usable?

The four peer reviewers asked questions and commented orally during the peer review meeting. They also provided written comments approximately two weeks after the meeting. All of the reviewers indicated that the ATHEANA method had made significant contributions to the field of PRA/HRA, in particular by addressing the most important open questions and issues in HRA, by attempting to develop an integrated approach and by developing a framework capable of identifying types of unsafe actions that generally have not been considered using existing methods. The reviewers had many (and sometimes similar) concerns about specific aspects of the methodology and made many recommendations on ways to improve and extend the method and to make its application more cost effective and useful to PRA in general.

This paper discusses the major comments received from the peer review team and provides responses (but not necessarily resolutions) to specific criticisms and suggestions for improvements. A list of the general strengths and weaknesses of ATHEANA, as indicated by the reviewers, is provided first. Next, specific comments bearing on major aspects of the method are presented and discussed. Finally, general comments related to improving the efficiency and usefulness of ATHEANA are addressed.

#### **General Strengths and Weaknesses of ATHEANA**

The reviewers' general opinion of ATHEANA is that the method represents a significant improvement in HRA methodology; it is a useful and usable method; and it is a "good alternative to first-generation HRA approaches." However, the method does not yet go far enough and therefore needs to be improved and extended. Several of ATHEANA's strengths, as indicated by the four reviewers, are listed below.

- 1) "Until now, in my opinion, there is no other published approach that tries to solve the problem of including EOC [errors of commission] in PSA in such an extensive way. Other methods address only parts of this. Overall, the general approaches and concepts developed in the ATHEANA-method are appropriate to deal with the problem of EOC. I think that the ATHEANA-method as currently documented contains a lot of important aspects for understanding and integrating EOCs into PRA. However, many aspects are only mentioned implicitly. An explicit and concise elaboration is necessary to assure practicability..."
- 2) "The real value of ATHEANA seems to be as a systematic way of exploring how action failures can occur. This is something that conventional HRA methods do not do well, if they do it at all, since they tend to focus on producing numbers. Although this use of ATHEANA does not really answer the need for an HRA approach, it might have a value in itself (as the comments from the demonstration participants expressed) and it might conceivably be decoupled from the HRA side. In that case a more streamlined method may be developed, that is less cumbersome to use. The demonstration of ATHEANA very clearly showed how it can be used to develop detailed qualitative insights into conditions that may cause problems, how it may generate a solid basis for redesign of working

procedures, training, and interface, and how it may be used as a tool for scenario generation. Each of these are significant achievements in their own right.”

- 3) “The method described in ATHEANA is certainly well suited for overcoming the difficulties encountered when applying more classical human reliability methods and focuses on the important issues of context and cognition that need to be tackled. Many aspects of the methodology are commendable and give great added value to the whole methodology. In particular, the following features are important:
- the details in describing many processes and steps in the application of the methodology;
  - the consideration for the crucial features that affect human cognition and behaviour in managing modern plants, included in concepts like the error-forcing context; and
  - the identification of the appropriate retrospective approach for the evaluation of the factors influencing behaviour and basic data for prospectively analysing the likely outcome of erroneous behaviour and probabilities.”
- 4) “Properly applied, the methods that comprise ATHEANA should be able to yield significantly more insight into the nature of human actions that can contribute to the occurrence of a core-damage accident. These methods clearly provide a framework for identifying some types of unsafe actions, and especially errors of intention, that would generally not have been considered using current methods. Moreover, they allow for a much more careful definition of the context and causes of these unsafe actions.

Without broader application of the methods, however, it is impossible to draw conclusions regarding the degree to which important actions that are not considered in present PRAs will be identified. It is reasonable to expect that some of the most important potential unsafe actions would be the result of subtle aspects relating to interactions among plant conditions or performance shaping factors that would be very difficult to postulate, even with the proper team makeup and extensive time available for the analysis.

What can be expected is that the methods will provide for the integration of understanding from the diverse team members that will lead to these new insights. This should be a synergistic process, allowing knowledge to be shared and captured in a way that enhances both the completeness and realism of the PRA, and the quality of training and procedures. A significant advantage of the method could be to provide a rationale for the characterization of the human failure events that often eludes us in present PRAs. While present methods may arguably yield reasonable quantitative results, they often fail to provide an understanding of the underlying causes of the human failures that are analyzed. Absent that understanding, it is very difficult to identify measures that can be taken to reduce the risk associated with unsafe actions. Consequently, it is often frustrating to identify a human action as risk-significant, but not to be able to give very satisfactory answers as to why, or what could be done to reduce that significance. With ATHEANA, on the other hand, the analysis of an unsafe action is necessarily truncated if an error forcing context cannot be identified.”

The above statements clearly indicate that the ATHEANA method has made significant improvements in HRA methodology and that the method, as documented, is a useful and usable tool. Perhaps not surprisingly, current members of the ATHEANA development team (the authors of this paper) agree generally with the

above statements. However, the reviewers were also very clear in indicating that, in their opinion, there are several important general shortcomings of ATHEANA. These are listed below.

- 1) "There seems to be an inconsistency in the level of models being used, ranging from EOO-EOC (errors of omission - errors of commission) over the information processing model to the notion of slips and mistakes. It would be interesting to consider how the search process could be strengthened while relaxing the dependence on the model(s)."
- 2) "There is no identifiable way of encompassing management and organization [M&O] factors or responding to the challenges of the broader socio-technical or contextual way of thinking (which also is seen by the conceptual problems in taking M&O factors into account in PSA)."
- 3) "Insufficient consistency in the terms and concepts used, and significant differences between what is written in NUREG-1624 and what was said at the review."
- 4) "The ATHEANA method is very cumbersome and presumably very costly. The guidance is too complex and depends too much on subject matter experts."
- 5) "The quantification method is weak, and the quantitative results (of the demonstration) are unsubstantiated. The quantification is excessively dependent on expert judgement, hence possibly has low reliability as a method."
- 6) "The qualitative results are good, but these might have been obtained in other ways, perhaps more efficiently. It is also doubtful whether a utility will undertake a significant effort just to get the qualitative results."
- 7) "The implementation of the basic approaches is sometimes not elaborated far enough from my perspective. This makes the use of the method in the current status difficult and may cause high variance between different users. I also observed that the document NUREG-1624 and the presentations on the peer-review are sometimes not in accordance to each other. In order to have a usable and profound method, the basics has to be refined and extended."
- 8) "Especially, I see the danger that the whole suggested procedure may fail if the role of the cognitive model (i.e. to work out and structure EMs [error mechanisms]) is not elaborated further. The cognitive model has a considerable effect on the consistency between EMs, the compatibility of prospective and retrospective analysis, the link between EFC [error-forcing context], EM and UA [unsafe actions] as well as the quantification procedure."
- 9) "The methodology clearly presents a dilemma. Its effectiveness results from forming a diverse, experienced project team to perform a comprehensive, broad-ranging analysis. Few organizations, however, appear to be in a position to undertake such an extensive analysis without clearly defined, commensurate benefits. Thus, even if it is an excellent methodology from a technical standpoint, it will not be very valuable if it will not be used."
- 10) "The potential wide application and popularity of the method are, however, associated with the *easiness of application* of the method and the *completeness* of the supporting information and data. The first issue (*easiness of application*) is related to the clear differentiation between retrospective and

prospective analysis, which contains also the question of applicability of the cognitive model. The method, as presented in the report, generates some confusion, especially for non-specialists in human factors, even though one could argue that the ATHEANA team should contain such expertise. The question of the availability and *completeness* of a reference database and clear tables of parameters and variables sustaining the HRA approach has, in practice, already been almost completely tackled and solved. What remains to be done is simply the clear definition of the connections between such databases and parameters on the one hand and models, paradigms and structure of ATHEANA on the other.”

Although the above set of comments is not necessarily complete in regard to the limitations of ATHEANA as indicated by the peer reviewers, it is thought that the selected set does represent the more important general limitations identified by the reviewers. Some of the above criticisms are responded to directly, but in other cases, some future decisions are required. The criticisms and responses are grouped below according to major aspects of ATHEANA.

### **The ATHEANA Framework and Underlying Models**

Two important aspects of the ATHEANA methodology are (1) the multi-disciplinary HRA framework (see Figure 2.1, NUREG-1624 [Ref. 1]) that describes the interrelationships between human error mechanisms, the plant conditions and performance-shaping factors (PSFs) that set them up, and the consequences of the error mechanisms in terms of how the plant can be rendered less safe, that is, UAs and (2) the human information processing or “cognitive” model (see Figure 4.1, NUREG-1624 [Ref. 1]) that is used to describe the human activities and mechanisms involved in responding to abnormal or emergency conditions and thereby assist analysts in searching for potential unsafe human actions. Several of the criticisms listed above (e.g., 1, 8 and 10) raise concerns about the descriptions and use of the framework and the cognitive model in ATHEANA. Essentially all of the peer review team had questions or concerns about these aspects of ATHEANA.

Regarding the multi-disciplinary HRA framework, several reviewers thought that the definitions and distinctions between the components of the framework and their interrelationships with each other and with the cognitive model were not sufficiently clarified. The reviewers considered this important because they correctly assumed that understanding the framework (and to some extent its relationship with the cognitive model) was important to understanding the ATHEANA methodological approach. One concern was exactly what was meant by “error mechanisms,” how they are used in ATHEANA, and whether or not the terminology was appropriate, given the underlying assumptions of ATHEANA, for example, people usually behave rationally and are led to UAs as a function of the circumstances. Another concern was that the distinction between error mechanisms, PSFs and plant conditions was not sharp enough.

Clearly, “crisper” definitions of these terms are needed in the ATHEANA documentation because they are used to guide analysts in their search for UAs and the associated EFCs. One goal of using the construct of error mechanisms is to convey to analysts that there are human information processing activities that may be appropriate in some circumstances, but not in others. Examples of such activities are provided in the ATHEANA documentation and they are elaborated to some degree in the discussion of the cognitive model (Section 4 of NUREG-1624). The main purpose of the discussion in Section 4 is to encourage analysts to think about the potential for human error in a different manner than has been done in other HRA methods and not necessarily to provide a complete and validated set of error mechanisms. It is not obvious that further elaboration of possible error mechanisms will necessarily facilitate the ATHEANA search process or the



quantification process. Nevertheless, the clear use of the construct of "error mechanisms" in the context of ATHEANA will be addressed. To the extent that additional explanation and elaboration of potential error mechanisms will facilitate the search and quantification processes, such work will be performed for later revisions.

Consideration will also be given to a couple of reviewers' suggestion that the term "error mechanism" should be dropped because human information processing is probably not limited only by processing "mechanisms," which implies structures, (e.g., processing is probably also limited by inappropriate processing strategies) and because the behavior that leads to UAs is only an "error" in hindsight. As is assumed by ATHEANA, the information processing performed may have been perfectly appropriate in most situations and is inappropriate only because of special circumstances; it therefore is not an error in the usual sense. Recommendations for a replacement term for the construct included "behavior mechanisms" or simply "cognition."

As noted earlier herein, another concern expressed by the reviewers was with the distinction between plant conditions, PSFs, and error mechanisms. It was argued that it is not always easy to determine whether a particular factor belonged in one category or another (e.g., whether procedures and instrumentation problems should be categorized as plant conditions or PSFs) and that it was necessary for ATHEANA to make the distinctions clear. One reviewer indicated that the PSFs should be standardized and made complete. The current ATHEANA documentation has acknowledged that, in some cases, the distinctions are not always perfectly clear, but the emphasis from the analysis point of view is to ensure that the factors relevant to the EFCs are considered. Although it may be possible for the ATHEANA team to develop a useful underlying model for grouping the relevant factors and this effort may be attempted for revisions to the method, the main consideration in the application of ATHEANA is that as many relevant factors as possible are considered in identifying the EFCs.

Other issues regarding the models used in ATHEANA concerned the use of the EOC-EOO distinction, the slips versus mistakes categorization in the context of the other models used in ATHEANA (e.g., see criticism 1), and the ability of the method to correctly consider crew-related factors when the cognitive model generally applies to information processing by an individual. The latter concern suggests that it might be useful to include a "crew interaction" model that could be integrated with the cognitive model. The team will examine the feasibility and usefulness of such an endeavor.

Regarding the slips versus mistakes categorization, several reviewers argued that this categorization was probably not necessary and at least one argued that it was inappropriate. The use of such terminology, which does presume an underlying model not explicitly adopted by ATHEANA, will be addressed in future revisions.

Finally, several reviewers also suggested that the framework and models used in ATHEANA be compared to other more familiar models from existing methods in order to elucidate the differences between ATHEANA and other HRA approaches. This would certainly be a useful addition to the ATHEANA report in that it would assist analysts in realizing the advantages to conducting an ATHEANA HRA. Clearly, revision of the ATHEANA documentation should discuss the uses and appropriate application of ATHEANA to various analysis tasks.

## **The ATHEANA Process**

This section addresses a variety of important comments on aspects of the ATHEANA process.

### *Retrospective Analysis*

The use of an ATHEANA-driven retrospective analysis of plant and other operational events was listed as one of the strengths of the ATHEANA process (see strength 3). More than one of the reviewers commented on the positive aspects of the use of retrospective analysis for assisting analysts in evaluating their plant and supporting the proactive HRA. In fact, their main concern was that a formalized, structured procedure, separate from the proactive search process detailed in ATHEANA, was not provided in the existing documentation. They suggested that a separate write-up and flow diagram be developed on how to perform retrospective analysis and on how it interfaces with the proactive analysis. Reviewers concerned with the definitions and relationships/connections between the elements in the framework and cognitive model also felt that clarification of these aspects would also greatly facilitate the retrospective analysis (see criticism 8). They argued for "taxonomies for actions, errors, and PSF" and clear rules for event decomposition in the retrospective analysis. In addition, they also suggested providing improved guidance on how to use the HERA database (Ref. 2) and the retrospectively analyzed events documented in Appendix B of NUREG-1624. [Note that HERA is a database being developed for the USNRC that contains documentation of significant events from nuclear and other industries. The events are represented from the ATHEANA perspective and in ATHEANA terminology.]

The ATHEANA team agrees that additional guidance on how to perform and use retrospective analysis and the HERA database would be useful additions to the ATHEANA documentation. Analysts would be able to learn more directly about the characteristics of ATHEANA and in addition to "self-training" on the ATHEANA "philosophy," framework, and models, they would better understand events that have occurred at their plant and how other events might occur in the future.

### *Prioritization Process*

Several of the criticisms listed above (e.g., 4, 6, and 9) indicate that the demands of applying ATHEANA may be cost and time-prohibitive for many nuclear power plants. One aspect of ATHEANA that was developed in an attempt to allow users to focus their limited resources was a process for prioritizing the more important accident scenarios. While the reviewers generally were supportive of the prioritization process, several suggested that the process be further improved and proceduralized. Specifically, they wanted a "greater consideration of the risk potential of possible human failure events (HFEs)" and (on the basis of information provided at the peer review on the results of the trial application of ATHEANA) an earlier identification and assessment of crew characteristics and other M&O factors that might make certain types of scenarios more likely to contain risk significant UAs than others.

Once again, the ATHEANA team agrees that improvements in the prioritization process, as suggested by the reviewers, would be useful. A characterization of the way plant crews interact with one another and approach accident scenarios would assist analysts in determining the types of scenarios likely to be problematic (see Appendix A, Section A.7, of NUREG-1624 for details). Explicit incorporation of other M&O factors (which is considered a weakness of ATHEANA; see criticism 2) at the prioritization stage may also be beneficial. It should be noted that there is nothing about ATHEANA that is inherently incompatible with the consideration of M&O factors (contrary to criticism 2). The main problems associated with accounting for M&O factors in

ATHEANA are that there are no currently accepted methods for modeling such factors, and the costs associated with the additional analysis may offset the benefits.

In addition to these two items, there were several other comments related to the ATHEANA process that the ATHEANA team, in principle, agree with. They include the following:

- Provide further guidance for the creative thinking/search process to lessen variability and interpretation, including providing guidance on how to "manage" group discussions. Also emphasize the need to document the process "as you go" and more closely link the documentation tables with the relevant sections of the search process.
- Stress more strongly the importance of modeling the support systems, in addition to the main safety systems, in searching for potential HFEs and UAs.
- Discuss to what extent dynamic reliability is or is not part of the process and why.
- Further stress where and how one treats organizational factors, team interactions, recovery, and dependencies

One additional comment on the ATHEANA process warrants a response from the ATHEANA team. It was suggested that there should be an explicit use of formal task analysis in conducting ATHEANA. While it is true that some of the existing HRA methods recommend the use of formal task analysis in order to understand the operators' tasks during accident scenarios, it is not clear that the additional costs associated with formal task analysis would necessarily be useful in applying ATHEANA. In conducting ATHEANA, the HRA team, using appropriate procedures, examines the crew's responsibilities during various accident scenarios and, when possible, conducts simulator exercises. It may be beneficial, however, to emphasize the step of carefully examining procedures relevant to particular accident scenarios early in the process of identifying potential UAs and their EFCs. This step is certainly part of task analysis and should assist analysts in identifying the more critical and likely UAs for further analysis.

### **The ATHEANA Quantification Process**

The reviewers raised several issues associated with quantification. These include the overall ATHEANA approach of identifying and quantifying situations where the likelihood of failure is very high, the methods used to quantify a UA in a particular EFC, and the effect of the various PSFs and plant conditions on the likelihood of failure. Other comments pertained to the need to address recovery actions and dependencies in the quantification process.

A basic premise driving the development of ATHEANA is that the HFEs that have heretofore been most problematic for identifying and assessing their impact on plant risk are those in which a particular context creates a very high likelihood of failure. This premise is in contrast to the premise implicit in most other HRA methods that there is a constant (and usually low) likelihood of human failure for any given accident scenario. (It is true that some HRA methods have moved beyond this simple assumption, but they have not been widely used and have rarely been applied in a systematic way.) Therefore, the search process and the associated quantification process are principally aimed at identifying those conditions in which the UA probability will be much higher than in other non-forcing conditions. However, this fact does not imply that the application of ATHEANA would never identify situations in which the probability of the UA, given the

EFC, is significantly less than 1.0. In such situations in which human error probabilities must be estimated, existing applicable HRA methods may be useful for quantifying the error probability, given the defined EFC.

Several reviewers suggested that the methods for estimating the probability of the UA be revised or broadened. We agree that alternative methods can be used. In the trial application, HEART (Ref. 3) was used because it most directly used conditions similar to those identified as EFCs in the scenarios, bearing in mind the data sources used in HEART and the level of description for the conditions under which the data were gathered. It is important to ensure that the method and data used to quantify the likelihood of an unsafe action in a particular EFC will be sensitive to those factors that create the forcing nature of the EFC conditions. An alternative approach that was suggested is to use a subjective-assessment method like SLIM-MAUD (Ref. 4). Such methods could be used in principle. However, the continuing difficulty is one of selecting appropriate anchor points for the assumed probability distribution. This problem has been raised previously in reviews of HRAs that have used methods like SLIM-MAUD in which the analyst provides the range within which a point probability is interpolated.

One reviewer suggested the use of tables for specific PSFs and plant conditions that showed their influence on the likelihood of unsafe actions. Such data could be derived from historical experience in the events reported in the database. However, this approach is at odds with the ATHEANA method, which considers the influence of PSFs and plant conditions to be an integral set of influences on performance, and not separable and discrete influences such as those reported in THERP (Ref. 5). In ATHEANA, the typical issue is "What combination of plant conditions and weaknesses in the displays, procedures, etc., has to occur to mislead operators into believing that action 'x' needs to be taken?" The key is that it is the combination, not each influence separately, that is important.

It is agreed that the analysis of recovery actions is problematic. In applying ATHEANA, the team has considered recovery on a case-by-case basis, looking specifically at ways the scenario may develop, where additional outside staff may become involved, and so on. The approach thus far has not been to treat recovery actions as separate from the initial UAs. Similarly, the method does not include explicit processes to model and quantify dependencies between actions. Clearly, future revisions and applications of ATHEANA must better address the analysis of recovery actions and dependencies.

### **Improving the Efficiency, Usefulness, and Consistency of ATHEANA**

Several of the comments from the reviewers (e.g., criticisms 4, 6, and 7) express concerns about the resources required to apply ATHEANA and whether or not the obtained results will be important enough and complete enough for users to justify the costs. A related concern is whether the method has been specified in enough detail and "elaborated far enough" to allow consistency in the results obtained by different analysts applying the method. Similar concerns regarding resource demands and completeness were raised by the participants of the first demonstration of ATHEANA, which was held in 1997 at a pressurized water reactor nuclear power plant (see Appendix A, Section A.7, of NUREG-1624 for details).

The ATHEANA team acknowledges that a broad and careful application of ATHEANA will require significant resources. Although the search for important HFEs, UAs, and their EFCs will never be trivial, it can be manageable. Thus, steps will be taken to improve its efficiency (some of which are discussed below). Will the resources demanded by the method be worth it? ATHEANA will identify demanding accident scenarios and potential UAs and EFCs that could lead to serious accidents. Whether or not the method will identify numerous events that result in large increases in calculated plant risk metrics remains to be seen.

Moreover, given the inadequacies of the HRA methods that were used to conduct the existing nuclear plant PRAs, it is impossible to know exactly what a realistic estimate of the baseline HRA contribution should be. Therefore, it is difficult to predict what kinds of changes in risk metrics to expect. In any case, the benefits of ATHEANA are much broader than those from performing revised PRA calculations alone. The improvements in HRA modeling to better identify operator vulnerabilities in accident scenarios and to better understand what are the contributors to operator performance will certainly be of significant benefit in assessing and managing plant risk. Nevertheless, it must be the case that the method can be applied without an excessive demand on licensee resources.

The peer reviewers and others identified several actions that will increase the effectiveness and efficiency of ATHEANA. These actions include the following:

- developing a computer-based user support system to guide the process and the documentation of the results,
- refining the prioritization process to facilitate identification of the types of scenarios and situations most likely to create problems,
- developing better guidance on when and how to develop and use simulator exercises to learn as much as possible about where and how unsafe actions can occur, and
- producing a "quick reference guide" that would allow analysts to bypass reliance on the NUREG document once they have some experience with the method.

Another issue raised by the peer reviewers concerns consistency in the application of the process and the potential for significant variability in results because of some of the "open-ended" aspects of ATHEANA, (for example, the creative thinking and brainstorming aspects of the process for identifying EFCs and the use of expert judgment in the quantification process). The ATHEANA team agrees that additional guidance is needed to ensure consistency in the results obtained using the method.

Finally, it should be noted that reviewers of the method suggested that the documentation provide estimates of the costs and resources required to perform ATHEANA and that criteria should be provided for when ATHEANA should be used. While the former suggestion may be difficult to implement until additional tests of ATHEANA are completed, it is a reasonable suggestion. Providing a listing of criteria for when use of ATHEANA is called for would seem to be straightforward and will be considered for the revision.

### **Other Useful Suggestions**

Several other comments received from the peer review team are worth noting because they are good suggestions that would improve ATHEANA. They include the following:

- ATHEANA should include an overview of PRA for participants without a background in PRA. Any training programs developed for ATHEANA could also provide such an overview, and aspects of PRA could be treated in more detail as the analysis progressed.
- It was recommended that a single "running" example be used while discussing the implementation process.

- It was recommended that additional examples for BWRs should be added. PWRs are overemphasized.

## Conclusion

Taken together, the comments from the peer review team indicate that the work performed in the development of ATHEANA has resulted in significant contributions to the field of HRA and that ATHEANA is a viable HRA method. However, the reviewers also indicated that there were important clarifications and improvements that needed to be made to ATHEANA. Clearly, many of the recommendations made by the reviewers would, if implemented, make ATHEANA a better, more effective, easier to use, and more "encompassing" methodology. However, a number of factors must be considered in determining which of the suggested changes are necessary, which would be useful but are not critical, and which would be useful but are currently impossible. The development of an HRA method such as ATHEANA is certainly limited by the state of current knowledge in a number of domains such as cognitive psychology, crew dynamics, and management and organizational factors. In addition, the unavailability of actual data from crew performance in nuclear power accidents or from other domains that might be generalized to control room performance certainly limits the ability of any HRA method to precisely predict performance. Other factors include the danger of over-complicating the method in attempts to be more precise and complete. It seems to the ATHEANA team that the most important goal is to provide a usable method that is as cost-effective as possible -- one that will allow analysts to identify, understand as much as possible, and quantify as accurately as possible, potential unsafe human actions that could lead to serious accidents in nuclear power plants or other domains. The explicit procedures, information, and guidance provided in ATHEANA certainly provides HRA analysts with a new and explicit set of tools to achieve this goal. To the extent viable changes recommended by the reviewers will further this goal, in particular by making the method more valid and easier to use, attempts will be made to incorporate them into the ATHEANA methodology.

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