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TRIAL APPLICATION OF A TECHNIQUE FOR HUMAN ERROR ANALYSIS (ATHEANA)

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ABSTRACT

The new method for HRA, ATHEANA, has been developed based on a study of the operating history of serious accidents and an understanding of the reasons why people make errors. Previous publications associated with the project have dealt with the theoretical framework under which errors occur and the retrospective analysis of operational events. This is the first attempt to use ATHEANA in a prospective way, to select and evaluate human errors within the PSA context.

I. INTRODUCTION

Existing approaches to human reliability analysis (HRA) address the seemingly straightforward question: What is the chance that the humans err, given nominal conditions; i.e., expected conditions under the accident? However, from the viewpoint of risk, there is a more important question to answer. The ongoing review of operating events throughout the ATHEANA project[1,2] indicates that people commit serious mistakes and actively decide to pursue the wrong course of action. In every serious instance identified during the review, the mistake was setup by both a complicating physical condition and a complicating human condition (negative performance shaping factor). Generally these mistakes have been errors of commission (EOCs). The question for HRA with respect to the most risk significant scenarios requires a subtle change in thinking: that is, to quantify the likelihood of the "error forcing condition," rather than predicting random human error in the face of nominal or best estimate conditions. Thus, the substance of this work is to search for, to identify and to quantify the probability of important error forcing conditions.

For the past year the project team has been at work developing search schemes for both human failure events (HFEs) and error forcing conditions (EFCs). The process begins with defining a search approach and continues by attempting to apply the approach through trial applications, then formalizes the process in a structured search algorithm. Several trial applications have been performed by the ATHEANA development team during this process.[3] The objective of the demonstrations was to determine if HFEs with special context can be identified that are not typically included in the probabilistic safety assessment (PSA) and that materially add to the risk. Quantification then calls for a multistage process that can involve both judgment and detailed calculations.

At this time in the project, guidance is being developed for analysts, including a *"Frame-of-Reference Manual"*[4] (draft form) that is intended to bring all practitioners to a common knowledge base and *"Guidelines for Implementing ATHEANA,"* a step-by-step description of the ATHEANA HRA process (not developed).[5] The HFEs to be analyzed are events that one would normally believe "cannot happen," however the event histories show that they do.[2] The challenge here is to identify special conditions that make these error likely.

II. APPLICATION: A STRUCTURED SEARCH FOR RISK SIGNIFICANT HFE/EFCs

At this time the search process includes several key properties:

- Structured search based on common knowledge base (*Frame-of-Reference Manual* draft) and plant-specific features

DISCLAIMER

- Existing plant-specific PSA provides the starting point for the search for HFEs; it permits identification of potential HFEs with a high likelihood of severe consequences

- Plant-specific operator training and emergency operating procedures are incorporated into the search

- Examples of human actions from the *Frame-of-Reference Manual*, based on the human error model and the review of actual event histories, set priorities for continuing the search through error mechanisms, performance shaping factors, and plant conditions

Much of the work to this point involves examining alternative ways to structure the information synthesized from the model of cognitive information processing[1] and the existing event analyses into priority ranked rules to enable the search for HFEs and EFCs to proceed efficiently. It requires the ability to restructure advice during the evaluation, reordering priorities based on plant-specific information and on the results of previous search steps. This then becomes the real step-by-step guidance to the analyst; i.e., under the broad direction of the future guidelines and the knowledge base of the *Frame-of-Reference Manual*, revised advisory tables become the reprioritized "instantiation" of the guidance for the search step at hand.

The application begins with an interesting initiating event and then works through the PSA to a point where the operators could intervene. The approach then shifts to a search for combined plant conditions and performance shaping factors that could make an unsafe act more likely.

III. TRIAL APPLICATION

The search for HFEs and EFCs looked at all initiating events and all top event success criteria in a fully rigorous application to a PSA. For the purposes of this example application and for PSAs that have not yet made a full commitment to apply ATHEANA we seek a structured search that attempts to set priorities, to identify first those HFEs that have the highest likelihood of introducing significant risk.

The application begins by selecting the initiating event to examine. In the existing PSA, the following initiating events have been identified:

<u>Initiating Events</u>

- Loss of offsite power
- Transients with loss of main feedwater
- Transients with MFW initially available
- Non-recoverable loss of DC Bus A
- Non-recoverable loss of DC Bus B
- Steam Generator Tube Rupture
- Large LOCA
- Medium LOCA
- Small LOCA
- Very Small LOCA
- Interfacing LOCA

To help set priorities, consider the following selection criteria for HFEs:

<u>Select initiating event--priorities</u>

- EOCs not already modeled
- Creates unfamiliar situation
- Operation history shows observed failures
- Occurs frequently—overconfidence when variant occurs

These criteria lead one to focus on cases where an operator can turn off an emergency system, for example high pressure injection or auxiliary feedwater. The operating history includes significant events in which emergency systems have been bypassed or turned off, including high pressure injection and auxiliary feedwater. Furthermore, despite simulator training, LOCAs create unfamiliar situations. Few operators have actually experienced a real LOCA, and few LOCAs will exactly match the specific cases modeled in accident analyses or be used for simulator training. For this first demonstration, a small LOCA is selected.

Given the small LOCA initiating event, the event tree from the PSA shows the following top events:

<u>Small LOCA top events and success criteria</u>

- RPS - reactor protection system
- HPI - high pressure injection requires 1/3 charging pumps
- AFW - auxiliary feedwater requires 1/3 AFW pumps
- PRV - requires 1 PORV to open
- ContSys - containment spray not required early in the small LOCA if fan coolers are operating
- OperDpres - Operator depressurizes the reactor coolant system so that low pressure recirculation is feasible
- CV - Core vulnerable to damage due to loss of containment cooling
- LPR - low pressure recirculation requires 1/2 LPR pumps
- HPR - high pressure recirculation requires 1/3 HPR pumps

The PSA defines the success criteria associated with each top event. In selecting the functional failure to examine for possible HFEs, we set the following priorities:

Select HFE functional failure—priorities

- Limited time to recover
- Creates unfamiliar situation

Walking through the event tree top events, HPR failures allow substantial time to recover, most of the other events are only required under unusual circumstances, have substantial time to recover, or provide a function backed up by diverse means. HPI, however, offers reasonably short time to damage, if it is failed. However, for an HFE to cause failure of HPI, a strong EFC would be required.

At this point, the analyst uses the *Frame-of-Reference Manual* to assist in the thinking process. A series of tables suggests alternative means by which HFEs, unsafe acts (UAs), and EFC elements can occur. The analyst must select among them, keeping an eye on priorities for selecting sufficient likely and severe cases that they may contribute to risk.

To select the HFE causing HPI failure, given a small LOCA, we establish the following priorities:

Select HFE—priorities

- What is feasible for this initiating event and system
- Error of commission
- Creates difficulty to recover

The first table in the Frame-of-Reference manual identifies functional failure modes for each PSA top event success criterion. For this example, only a few possibilities are reasonable. We select "equipment fails to continue operating for duration and mission time." For each functional failure mode, the table suggests possible human failures. We select "equipment inappropriately terminated."

The next step is to select the unsafe act from those suggested in the Frame-of-Reference manual. The priority recommendations for selecting UAs are based on cases that will be particularly difficult to recover from, either because the machine is in an unforgiving condition or because the psychological factors affecting the operator make human recovery unlikely.

Search for UAs—priorities

- Physically unrecoverable slip
- Slip or lapse induced mistake
- Mistake

Among the suggestions for UAs associated with the HFE "equipment inappropriately terminated," the only one that is reasonable for HPI at this plant is "equipment operation stopped before system/function success is achieved." No physically unrecoverable slips were discovered by the analysis team. Therefore, we will need to keep in mind that we seek an EFC, such that the UA-EFC pair is representative of a mistake. Such a mistake, because of the intention of the operator, will be difficult to recover.

Before continuing, it is appropriate to review the process of the search as described in the *Frame-of-Reference Manual.* We proceed following a sequence of search formalisms under the assumption that the operators act rationally, given their situation assessment. Thus we must look for "rules" of action, both formal and informal, that operators will rely on. The *Frame-of-Reference Manual* provides a check list of how to search for "rules" that might affect operator decisions. It goes beyond the formal procedures to determine, on a plant-specific basis, what informal and supposedly displaced rules might be within the operators' experience. Then we must consider: 1) how the operators might become convinced that a good rule does not apply, 2) that the rules criteria are met when they are not, or 3) that a bad rule should be applied.

The following are topics of another paper at this conference and, hence, are not included here:

- consideration of the rules that apply,
- the information needed to use the rules, and
- the ways that the formal rules could appear to be met when, in fact, they have not been met.

The rules are identified below:

- Formal Rule
  - Emergency Operating Procedure ES 0.1, Step x, SI termination criteria
- Informal Rules
  - "Don't go solid in the pressurizer"
  - "Stop spurious SI"
  - "Protect pump when trouble alarm actuates"

These rules require the following information:

- Formal Rule
  - Pressurizer pressure
  - Pressurizer level
  - Subcooling margin
  - Secondary heat sink

- Informal Rule

  - Pressurizer level ("Don't go solid")
  - Pressurizer level and pressure ("Spurious SI")
  - Pump alarm or pump amps or noise ("Protect pump)

Note that following the informal rules would create the HFE under consideration. These rules can overwhelm the formal rule under extremely demanding situations. For now, however, we focus on the formal rule.

We seek an EFC that is a combination of plant conditions and performance shaping factors (PSFs) such that the UA-EFC pair is likely to produce a mistake, a conscious decision to pursue, what will turn out to be, an unsafe course of action. To that end, it is necessary to conduct a plant-specific search using the *Frame-of-Reference Manual.*

Search tables in the *Frame-of-Reference Manual*

- Information problems
- Interpretation problems
- Failures in monitoring
- Confusing plant physics
- Confusing physics algorithms imbedded in instrumentation
- Confusing plant conditions

This review leads us to identify the following possible conditions relevant to "terminate HPI inappropriately during a small LOCA:"

- Believe pressurizer pressure is increasing due to faulty or miscalibrated pressure instruments (about 1×10^{-3}/d)

- Believe RCS level is high or increasing due to a LOCA via the pressurizer PORV (about 15 % of small LOCAs)

- Likelihood of unsafe action given context (about 0.1)[6,7]

Thus the frequency of this HFE-EFC pair is 2×10^{-7}/yr, a small but significant contribution for a single PSA cutset.

IV. CONCLUSIONS

It is possible to identify HFEs not generally included in current PSAs and associated EFCs that have an observable impact on the mean frequency of core damage in the PSA.

The HRA application demonstrates the potential of the new approach in the support of PSA. It remains to fully develop the *Frame-of-Reference Manual* and the *Implementation Guidelines* and to apply these techniques to a complete PSA.

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