Development of Human Reliability Analysis

Regulatory Guide (RG) 1.200 provides an acceptable approach for determining the technical adequacy of PRA results for risk-informed activities. However, RG 1.200 (including the probabilistic risk assessment (PRA) standards reflected and endorsed by RG 1.200) is a high-level regulatory guide, addressing what to do but not how to do it. Consequently, there may be several approaches for addressing certain analytical elements, which may meet the RG 1.200 and associated standards, but may do so by making different assumptions and approximations and, therefore, may yield different results. This is particularly true for human reliability analysis (HRA) for which many methods are available to analyze the human actions modeled in PRA. The staff is addressing this issue by developing guidance documents to support the implementation of RG 1.200.

This work supports the NRC's action plan for stabilizing PRA quality expectations and requirements (described in SECY-04-0118 and SECY-00-0007). It also is responsive to the November 8, 2006, staff requirements memorandum (SRM) (SRM-M061020) in which the Commission, based on ACRS concerns, directed the staff to propose a single model for the agency to use or guidance on which model(s) should be used in specific circumstances. The following activities are addressing HRA improvement needs:

(1) HRA Method Benchmarking:

Participated in the International HRA Empirical Study in an effort to benchmark HRA methods by comparing HRA predictions to crew performance on a nuclear power plant simulator.

The International HRA Empirical study was a multinational, multi-team effort supported by the Organization for Economic Co-Operation and Development (OECD) Halden Reactor Project. The Halden Reactor Project provided facilities, crews, and expertise to collect and analyze simulator crew performance data and HRA analyst teams from multiple organizations used their preferred HRA methods to analyze and predict the performance of these crews. The objective of the study was to develop an empirically-based understanding of the performance, strengths, and weaknesses of the various HRA methods used to model human response to accident sequences in PRAs.

This study was the first of its kind; no previous HRA benchmarking studies have been performed using crew simulator data. Its pilot phase is documented in NUREG/IA-0216, Vol.1, "International HRA Empirical Study – Phase 1 Report, Description of Overall Approach and First Pilot Results from Comparing HRA Methods to Simulator Data," November 2009 (Halden report HWR-844). Its second phase consisted of the analysis and comparison of HRA predictions for nine steam generator tube rupture (SGTR) human actions and is documented in NUREG/IA-0216, Vol. 2, "International HRA Empirical Study – Phase 2 Report, Results from Comparing HRA Method Predictions to Simulator Data from SGTR Scenarios," (Halden report: HWR-915), August 2011. Phase 3 consisted of the comparison of four loss-of-feedwater (LOFW) human actions and is documented in NUREG/IA-0216 Vol.3, "The International Empirical Study – Phase 3 Report – Results from Comparing HRA Method Predictions to Simulator Data from LOFW Scenarios," (Halden report HWR-951), published in 2014.

The overall findings of the study were documented in NUREG-2127 (HWR-373), entitled "The International HRA Empirical Study – Final Report – Lessons Learned from Comparing HRA Methods Predictions to HAMMLAB Simulator Data," published in August 2014. The results of the Empirical Study provide a technical basis for improving individual methods, improving existing guidance documents for performing and reviewing HRAs (e.g., NUREG-1792, HRA Good Practices), and developing additional guidance and training materials for implementing individual methods.

(2) HRA Method Improvement Using US Simulator Runs:

The International HRA Empirical Study clearly identified important strengths and weaknesses of the various methods and identified areas for improvement in HRA methods and practices. In particular, an important conclusion from the study was that improving the qualitative analysis aspects of HRA methods could increase their robustness and reduce some of the sources in the variability of results that were seen in applications of different methods. However, since there was only one case in the International study where the same HRA method was applied by different teams, it was difficult to clearly separate method specific effects from differences created by the analysts' application of a given method. Thus, in addition to examining differences across methods, a major objective of the US simulator study (performed on a US nuclear power plant simulator) was to test the consistency and accuracy of HRA predictions among different analyst teams using the same methods. A particular area of interest in these comparisons was examination of the qualitative analysis performed by different methods and teams to identify shortcomings that contribute to inconsistencies in results and to determine the extent to which the shortcomings are due to analyst differences or due to inherent shortcomings in the methods.

To accomplish the goals of the study, 4 crews from the plant performed 3 different scenarios: 1) a Loss of Feedwater followed (after recovery of feedwater) by a Steam Generator Tube Rupture, 2) a Loss of Component Cooling Water and Reactor Coolant Pump seal water, and 3) a basic Steam Generator Tube Rupture. Crew performance on several human failure events that would normally be modeled in a PRA was evaluated and compared with the predictions from 9 human reliability analysis teams using 4 different methods (ATHEANA, SPAR-H, EPRI Calculator, and ASEP/THERP). Both qualitative and quantitative predictions are being evaluated.

The results have been used to:

- Assess the impact of potential limitations in the data collected in the International Empirical Study as described above.
- Provide an improved basis for determining how to best improve HRA methodology and use this information as an input to the HRA Model Differences Project.

(3) Address HRA Method Differences:

Many methods are available for HRA. There is evidence that the results associated with a particular human failure event analysis could vary depending on the HRA method used and/or the analyst applying the method. Because HRA results and insights are frequently used to support risk-informed regulatory decision making, the NRC continues to improve the robustness of PRA/HRA through targeted activities (e.g., supporting and endorsing PRA standards developed by professional societies). Recognizing that HRA method differences contribute to the variability of PRA/HRA results, the Commission directed the Advisory Committee on Reactor Safeguards (ACRS) (SRM-M061020) to work with the staff and external stakeholders to evaluate the different human reliability methods and either propose a single method for the agency to use or guidance about which method(s) should be used for the different regulatory applications.

The Office of Nuclear Regulatory Research (RES) has taken the lead in addressing SRM-M061020. The ACRS has kept abreast of developments and provides input through periodic meetings. This work is performed collaboratively with the Electric Power Research Institute (EPRI) under a RES/EPRI Memorandum of Understanding and its update.

The main tasks of this work include: (1) Identification of current and emerging regulatory applications in which HRA results could have an impact on the decision; (2) identification and evaluation of currently available methods for their suitability and adequacy to treat human performance issues associated with the various regulatory applications and domains of interest (e.g., event analysis for shutdown operations); (3) development of a cognitive foundation for HRA through synthesizing literature on why humans make errors; (4) development of a general HRA methodology based on the cognitive foundation for all NPP HRA applications; the methodology, referred to as "Integrated Human Event Analysis System (IDHEAS)," integrates the strengths of the existing HRA methods into a unified HRA structure and uses new components to address the key limitations in current methods; and 5) implementation of the general methodology for HRA in internal, at-power events.

The development of the new HRA method needs to go through all stages of new method development: (1) developing a technical basis to understand human performance under accident situations from cognitive sciences and operational experience; (2) constructing a method for analyzing human performance and estimating human error probabilities supported by the technical basis; (3) developing tools for using the method; (4) reviewing and testing the work; (5) documenting the results and the development process; and (6) producing training materials and user guides. These efforts are targeted to produce a HRA method that is well understood and appropriately characterized for its suitability and usefulness in different regulatory applications. The staff completed the development of IDHEAS for internal, at-power events, tested the method, and developed training materials. The method is documented in NUREG-2199, Vol.1.