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 PRA standards reflected and endorsed by RG 1.200) is a high-level regulatory guide, addressing what to do but not the 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 analyses (HRA) for which many methods are available to model mitigative actions in PRAs. The staff is addressing this issue by developing lower level 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 evaluate different human reliability models in an effort 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: Participate 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 is 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 is 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 probabilistic risk assessments (PRAs).

This study is the first of its kind; no previous HRA benchmarking studies have been performed using crew simulator data. Its pilot phase has been 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, 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 consists of the comparison of four loss-of-feedwater (LOFW) human actions and will be documented in NUREG/IA 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), to be published in 2014.

The overall findings of the study are 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 will 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.

The study has also produced many conference papers, presented at the annual Institute of Electrical and Electronics Engineers Conference on Human Factors, August 2007, at the American Nuclear Society International Probabilistic Safety Conference 2008 (PSA8), September 2008, and at the International Conference on Probabilistic Safety Assessment and Management (PSAM) conferences: PSAM9, May 2008, PSAM10, May 2010, and PSAM 11, June 2012.

(2) HRA Method Improvement Using US Simulator Runs: As noted above, RES participates in and supports the International HRA Empirical Study to benchmark HRA models by comparing HRA results to empirical data generated through crew simulator runs. Although final documentation of this study is not yet complete, the International HRA Empirical Study has 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 are 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, is 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 is 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.

Two other potential limitations of the International study are also addressed in the US study:

First, in the International study, the HRA teams were unable to visit the Halden simulator and collect HRA related information through interviews with plant operators and trainers and through observations of actual operating crews in the simulator, as is typically done in performing an HRA for a NPP PRA. This type of information was provided to the HRA teams to the extent possible by the study team in the International study and the HRA teams were allowed to submit written questions that were answered by the study team and plant personnel as needed. Some of the HRA teams in the International study felt this significantly limited their ability to perform an adequate HRA. In the US study, the HRA teams were able to visit the reference plant and collect information relevant to performing their HRA as it would normally be done in a PRA.

Second, there was some concern that because the international study was based on the results of simulator runs using European crews at the Halden Reactor Project, the results might not be directly generalizable to what would occur with US nuclear power plant crews. Some of the HRA teams in the international study thought that their expertise was more geared to understanding what US crews would do and that their US bias may have influenced their decision-making in applying their HRA method. Thus, the US study served as a check against the effects of such bias on the results.

In SRM-M090204B, dated February 18, 2009, the Commission directed the staff "to continue to pursue possibly working with EPRI, INPO, and/or international partners to test U.S. nuclear plant operating crews' performance in a variety of situations and keep the Commission informed on the progress in developing a human reliability analysis (HRA) database and benchmarking projects." Thus, the US

Empirical Study is directly responsive to this SRM.

To perform the US Empirical Study, RES established an MOU with a US utility volunteering to participate in this study by offering simulator facilities, crews and expertise to support the design and execution of the experimental runs. Further, RES initiated work with the objective to evaluate HRA methods currently used in regulatory applications through a comparison of HRA predictions to crew performance in simulator experiments performed at the US nuclear power plant. The Halden Reactor Project, Idaho National Laboratory, Sandia National Laboratories, Paul Scherrer Institute (Switzerland) and EPRI are also participating and supporting the study.

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 sealwater, 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.

A workshop was hosted by the NRC in June, 2011 to discuss the preliminary results from the study with the study participants. Based on the input from the workshop participants, the data analysis is continuing. Plans are to complete a NUREG documenting the experimental design, results, and conclusions of the US study and another NUREG discussing the overall conclusions and lessons learned from both the International and US studies in early 2015.

The results will be 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 (Item 3 below).

(3) Address HRA Model Differences: Many models are available for HRA. There is evidence that the results associated with a particular human failure event analysis could vary depending on the HRA model/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 model 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 models and either propose a single model for the agency to use or guidance about which model(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 (ML070740114 and its update, ML100490657).

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 a cognitive foundation for HRA through synthesizing literature on why human makes errors (4) development of a generic HRA methodology based on the cognitive foundation for all NPP HRA applications; and 5) Development of a HRA method for internal, procedural HRA analysis that that integrates the strengths of the existing HRA models into a unified HRA structure and have new components to address the key limitations in current models. The new method is referred to as "Integrated Decision-tree Human Event Analysis System (IDHEAS)."

The development of the new HRA method needs to go through all stages of new model 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 model; (4) reviewing and testing the work; (5) documenting the results and the development process; and (6) producing training materials and user guides. The staff is currently engaged in the development of the method, sought to be ready for pilot testing and revision in 2014 and 2015. The staff expects to complete and the work by December of 2015.

The staff believes that these efforts will result in producing a HRA method that is well understood and appropriately characterized for its suitability and usefulness in different regulatory applications.

Primary Priority: High
Secondary Priority: Medium

Project Considerations: The HRA guidance addresses many issues associated with the use of HRA in decision-making, including the suitability of an individual method to a regulatory application, consistency among HRA practitioners in implementing HRA methods, and the absence of guidance on the rigor needed for quantification of human reliability.