How do you Define a Human Reliability Analysis Expert?

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ABSTRACT

Human reliability analysis (HRA) is an important part of probabilistic risk assessment (PRA) and is recognized as needing improvement to ensure that decision makers are using reliable results in risk-informed decisions for the current reactor designs in which the human plays an important role in ensuring plant safety.

In pursuing its risk-informed regulatory framework, the Nuclear Regulatory Commission (NRC) has undertaken many activities for improving the technical acceptability of PRA most of which has been pursued collaboratively with domestic and international organizations. In the HRA area, example activities are: the International Empirical HRA Study performed under the umbrella of the OECD Halden Reactor Project, the Office of Nuclear Regulatory Research (RES) and Electric Power Research Institute (EPRI) collaborative work on fire HRA, and the RES/EPRI collaborative work to address issues related to the differences of HRA methods. Such activities address various facets of HRA including:

- the development of acceptable practices for the HRA process as a whole
- the determination of the suitability of HRA methods to the application, and
- the implementation of a HRA method, that is, how and to what degree a method is applied as intended by the developers.

In addressing these topics, the issue of HRA expertise comes into play. Although HRA has been an important part of the overall PRA, this issue may have not been as crucial in the past, when the PRA was used primarily to identify plant improvements and when PRAs/HRAs were, in general, performed by experts who had a good understanding of the plant intricacies and interfaces with humans.

In general, PRA is an interdisciplinary field that needs the input of experts from various disciplines. However, it can be argued that there is a lack of focus on the interdisciplinary nature of HRA. PRA reviews and recent studies support this concern. For example, the review of individual plant examinations (IPEs) showed that, in general, equipment dependencies were handled well, but this was not the case for human event dependencies. More recently, early results of the International HRA Empirical Study indicate that differences in the level or nature of the analysis performed by the HRA analysts has an impact on the results. An early lesson from the Empirical Study is that methods should include guidance on how to analyze scenario characteristics to assist the analysts in understanding the cognitive and execution demands on operating crews. The authors argue that guidance only cannot be a substitute for experience; HRA involves judgments which can be frequently difficult unless the right mix of expertise is involved. So, although some methods may provide better guidance, issues related with HRA implementation practices go beyond individual methods.

Determining the qualifications of HRA expertise and developing “qualification curricula” and training materials to improve the technical acceptability of HRA practices is a must and needs to be addressed earlier rather than later. How do you define an HRA expert? The objective of this paper is to put in notice the need for developing HRA as

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professional field and, hopefully, create a momentum for addressing this important issue.

1 Introduction

For the current reactor designs, in which the human plays an important role in ensuring plant safety, human reliability analysis (HRA) is an important part of probabilistic risk assessment (PRA) and is recognized as needing improvement to ensure that decision makers are using reliable results in risk-informed decisions. For the new and advanced reactors, HRA also may play an important role, given the new features and limited understanding of the role of human in the safety of these reactors.

Although HRA has always been an important part of the overall PRA study, the performance of HRA may have not been as crucial in the past, when the PRA was used primarily to identify plant improvements and when PRAs/HRAs were, in general, performed by experts who had a good understanding of the plant intricacies and interfaces with humans. In addition, the practice of HRA has changed and evolved over time as a result of the different PRA applications it has supported.

In this paper, we return to the history of HRA practice, and compare this history with current needs in the USNRC and industry, in order to propose our definition of an HRA expert or analyst.

2 Historical Perspectives

Most texts that examine the history of HRA (e.g., Reference 1) agree that the roots of HRA were formed in the 1950s when human factors began to be a concern. However, the notion of human reliability did not appear until the 1960s and true HRA for nuclear power plants (NPPs), in the sense of supporting PRA, did not occur until the Reactor Safety Study, or WASH-1400 [2], was performed. In this study, the first HRA method used was the "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications" or THERP [3].

2.1 The PRA/HRA "Takeoff"

Although WASH-1400 was the beginning for HRA/PRA, this technology was not immediately embraced. The 1979 accident at Three Mile Island Unit 2 (TMI-2) arguably was a big influence on the growth and acceptance of HRA and PRA. This event caused the USNRC and the industry to review and improve many aspects of US NPP design and operations, including the assessment of safety or risk.

Regarding HRA, one important result of the TMI-2 accident was the historical convening of the first and second "Myrtle Beach" conferences on human factors and nuclear safety, held in December 1979 and August-September 1981, respectively. These conferences jumpstarted many activities related to human factors and HRA. Follow-on "Monterey" conferences in 1985 and 1988 continued the active forum for information exchange and discussion for HRA analysts and researchers. At the same time, an increasing number of NPP PRA applications were being performed; first, as utility initiatives, and later, in response to NRC's Individual Plant Examination Generic Letter 88-20 [4] that requested licensees to perform PRA-like study for the purpose of identifying and addressing vulnerabilities.

In these early years of HRA/PRA, everyone learned their respective disciplines, building on the experience from WASH-1400. Many analysts/practitioners learned the discipline through on-the-job mentoring and on-the-job training, supplemented by the healthy exchange of information between HRA analysts mentioned above (e.g., Monterey conferences, paper publishing). Because this timeframe was characterized by lots of HRA/PRA work, especially for NPPs, there were many opportunities for learning. Other industries (e.g., chemical processing) also began to use the basic tools of HRA and PRA.

THERP was being applied to many PRAs, but many new HRA quantification methods also were developed by analysts and researchers who wanted to address a variety of issues raised including:

- initial criticisms of THERP (i.e., comments provided by the Lewis Commission Report [5],
- more general criticisms of the NPP industry as part of the fallout from the TMI-2 event,
- feedback and information from operational personnel at plant sites on human performance issues.

As a result, a variety of HRA methods and approaches were available to HRA analysts during this time.

HRA continued to be a focus for development going into the 2000s, but it seemed to have had multiple objectives or focuses. On one hand, efforts were made to better model and quantify human performance. Methods such as CBDT [6] and the so-called, second-generation methods (e.g., ATHEANA [7], MERMOS [8], CREAM [9]) were developed to incorporate the advances made in understanding cognitive aspects of NPP operator performance (including modeling errors of commission), and in developing both the qualitative analysis and the quantification aspects of HRA . The development of these newer methods, however, brought forth the need of using a multidisciplinary approach, involving varying inputs from psychologists, cognitive or behavioral scientists, and HRA/PRA practitioners.

Other efforts were made to address the need for performing HRA in a simplified manner, usually to support a specific type of PRA or HRA application. One example is the SPAR-H HRA [10] method which was developed to support NRC's simplified PRA analyses. Another is the EPRI's HRA Calculator [11], a computerized tool for documenting the inputs and generating the results from several HRA methods, simplifying the job of applying HRA.

These different focuses of HRA drove the HRA application practices into somehow conflicting paths. The newer methods emphasized the need for interdisciplinary teams. On the other hand, the "simplified HRA" approaches were to be performed by just following the steps of a method's document, creating an impression that HRA can be performed without any special capabilities to understand human performance and/or without the consolation and interaction with experts who understand the plant phenomenology involved in human actions being analyzed. Such practices resulted in a general confusion as to what is needed to do an HRA and who is qualified to perform HRA. Although a few efforts for addressing how to perform HRA were made, one of the most significant being the EPRI-published SHARP1 [12] in the early 1990s, it appears that an expectation that HRA can be performed by anyone who can follow documented instructions (e.g., a report or a "blackbox" computer code), has become the acceptable.

2.2 A Place for HRA/PRA

With the establishment of its policy statement on the use of probabilistic risk assessment (PRA) [13], the 1990s and, more importantly, the 2000s can be characterized by the beginning, and then rapid growth, of risk-informed applications of HRA/PRA. Regulatory Guide (RG) 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis" [14] marked the beginning of risk-informed regulation allowing licensees to use their PRA for performing plant modifications.

The use of PRA results in regulatory decision making, however, raised the issue of the quality of PRA being used and resulted in the initiation of a plethora of NRC and industry activities for addressing PRA quality issues. One of the most important NRC activities is the development and revision of RG 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities" [15] which provides high level guidance on the acceptability of PRA/HRA results in regulation and endorses (with exceptions) the various PRA standards being developed by professional organizations, and specifically by ASME and ANS. Such activities indicate the Commission's focus on ensuring that the quality of PRA being used in regulatory decision will be commensurate to the decision being made.

With respect to HRA, the NRC developed NUREG-1792, HRA Good Practices [16], a guidance document that directly supports implementation of RG 1.200, and performed an evaluation of HRA methods with respect to these good practices, documented in NUREG-1842 [17]. Through both of these activities, it became apparent that there is a need to address HRA quality issues associated with the method itself, as well as how the method is applied. While NUREG-1792 provided, at a high level, the "good practices" for performing HRA, it also is important to HRA quality that analysts have the capability to both understand and incorporate these "good practices" into their analyses.

3 Current HRA Needs and Activities

Currently, activities supporting continued improvement in HRA/PRA quality are still an important priority to the NRC. In addition, new types of HRA/PRA applications need to be supported (e.g., new and advanced reactors, fire, seismic).

To this end, the NRC and the industry are both supporting many collaborative efforts aiming to improve and expand HRA capabilities. Some example projects are:

- International Empirical HRA Study performed under the umbrella of the OECD Halden Reactor Project
- collaborative work between the Office of Nuclear Regulatory Research (RES) and Electric Power Research Institute (EPRI) on fire HRA,
- RES/EPRI collaborative work to address issues related to the differences of HRA methods

Within this projects, various facets of HRA are being addressed, such as:

- the development of acceptable practices for the HRA process as a whole,
- the determination of the suitability of HRA methods to the application,
- the implementation of a HRA method, that is, how and to what degree a method is applied as intended by the developers.

However, these activities also point to the need to recognize and develop HRA as a discipline. Early results from the International HRA Empirical Study [18] have provided insights that can shed light on the topic of needed improvement in HRA applications. Examples of such insights are:

- that methods should include guidance on how to analyze scenario characteristics to assist the analysts in understanding the cognitive and execution demands on operating crews,
- that analysts' evaluations on the degree to which a performance shaping factor influences crew performance can have an impact on the HRA results, and
- there is a need for improved guidance on how exactly methods should be applied.

For example, the Pilot of this study indicates that the analyst's capability to identify key performance drivers and, therefore, appropriately characterize and evaluate human failure events appears to be dependent on the type of or the level of detail in the investigation performed to understand the scenario and the factors likely to affect the crews' performance. And the methods should have improved guidance as to how performance drivers should be identified and handled. However, the authors of this paper argue that improved guidance alone cannot assure that a quality HRA will be performed. Two additional, important ingredients are:

1. The need for HRA to be performed by interdisciplinary teams.
2. The need for HRA experience in performing the analysis.

Guidance cannot be a substitute for capability because HRA involves judgments which frequently are difficult to make unless the right mix of expertise is involved. Although some methods may provide better guidance than others, this benefit cannot compensate for the lack of either of the two ingredients above.

Beyond the International HRA Empirical Study, there is substantial evidence that shows that, frequently, methods are not applied as intended by the method developers. It is argued that many of today's HRA problems do stem from a historical lack of good integration of the disciplines involved in HRA which needs to be addressed as part of the PRA technical acceptability efforts. Recognition of the need for improving HRA quality also has prompted the Commission's Staff Requirement Memorandum (SRM)-M061020 [19], which directed the staff to address the issue of HRA model differences—including examining whether the NRC could adopt a single model for all HRA applications or whether it should adopt more than one—and to provide explicit guidance on the applicability and implementation of each model. With this last statement, the Commission has directed the staff to address HRA implementation issues, of which, a crucial one is the analysts' expertise to perform an HRA analysis.

4 Who is an HRA Expert?

Many terms are used to characterize the practitioners in the HRA field: HRA analyst, HRA/PRA analyst; HRA practitioner; HRA developer; HRA expert. Although an individual can be an HRA method developer, HRA practitioner, and PRA expert/practitioner; these terms are not interchangeable. For example, some developers of the more recently developed HRA methods have not been practitioners.

PRA, in general, is an interdisciplinary field that needs the input of experts from various disciplines. It seems that, for some PRA tasks, experts can perform these tasks with minimum input or interaction with experts in other disciplines. For example, a systems' engineer can develop fault trees without relying on input from other engineering areas once success criteria, other inputs, and assumptions are specified.

When it comes to the practice of HRA, however, this same analysis approach does not seem to work as well, as discussed in the sections above. For instance, without the assistance of human performance experts, engineers may not be able to appropriately apply HRA methods. Similarly, behavioral science experts, who do not have an engineering and/or operations background, often cannot understand why and how and accident sequence may evolve in order to appropriately evaluate the human failure events modeled in a PRA. Furthermore, there seems to be resistance to getting assistance from experts from the appropriate disciplines, especially, with respect to the additional resources that may be required. And yet, people who have not developed this interdisciplinary capability or identified an appropriate team of experts, perform HRAs.

It can be argued that this lack of focus on the interdisciplinary nature of HRA has hurt HRA over the years. PRA reviews and recent studies support this concern. For example, the review of individual plant examinations (IPEs) showed that, in general, equipment dependencies were handled well, which was not the case for the handing of human event dependencies. Inappropriate treatment of dependencies in a PRA can result in wrong plant-risk estimations which, in turn, could allow decisions to be informed by faulty risk findings.

Consequently, the authors of this paper believe that an "HRA expert" is a person that has developed an in-depth understanding of the equipment performance and human performance aspects as well as the modeling needs in these areas. An HRA analyst or practitioner, however, is a person who can perform HRA using one or more methods. Such a distinction can help focus the discussion of this paper on what it takes to be an HRA practitioner, rather than expert. The authors believe that we need both: experts who can lead the field in addressing existing and emerging needs, as well as practitioners who have the capability to appropriately perform an HRA or gather the right experts to perform it. Of course, an HRA expert also is a practitioner—however; correct characterization of people's roles may help addressing some of the confusion that exists when it comes to the HRA field.

An HRA expert may not need to have a degree in the behavioral sciences, if he/she has an engineering degree as well as competence in PRA. However, such an HRA expert also should have developed an understanding of human performance issues related to accident conditions. Similarly, an HRA expert may not need to be an engineer, if he/she has developed over the years an understanding of how important is to carefully take into consideration the particular plant conditions and equipment performance aspects pertaining to the human failure event being analyzed. In both cases, the HRA expert should be able to identify and integrate the expertise and capabilities of other experts (e.g., engineering, plant operations, and thermal hydraulics) into his/her analysis.

As the use of PRA has become mainstreamed and focused on answering specific questions, developing HRA expertise, including becoming a team leader for the variety of experts needed to perform HRA, has become more and more important. Determining the qualifications of HRA expertise and developing "qualification curricula" and training materials to improve the technical acceptability of HRA practices is a must and needs to be addressed earlier rather than later.

5. The challenge of the future

In the coming years, there are many potential applications of HRA/PRA, including support for upgrades to the existing fleet of NPPs and new and advanced reactors, as well as the need to advance HRA/PRA capability is such areas as fire, low power and shutdown, seismic events, and accident management.

These anticipated HRA/PRA applications have elevated the need for the NRC to develop its in-house HRA capability and help to advance the discipline of HRA, in general. While past and continuing NRC research (both alone and in collaboration with industry or international partners) provides support to both of these needs, further steps appear necessary.

First, as determined by the authors of the International HRA Empirical Study, it should be recognized that HRA should be performed by "experts." Second, the authors of this paper have concluded that the discipline of HRA should be explicitly recognized as a important element of any risk-informed organization, with the following support needing to be developed:

- Up-to-date HRA/PRA curricula, including material related to all aspects of HRA,
- Requirements for learning the discipline of HRA,
- Programs on how to "build" HRA expertise within an organization.

A difficulty with building HRA expertise has to do with the fact that it mixes very different disciplines: systems engineering and behavioral science. For example, the terminology used to explain human performance by human behavioral specialists seems to bring some of the barriers in communication. In addition, it appears that the way of thinking and approaching "human performance" from the behavioral science point of view seems to need to be reconciled with the way of thinking of the engineer. Attitudes, such as "I know human performance—that is my job, versus, I know my plant, procedures, and so forth," have been used as a basis for not consulting with human performance experts. Such attitudes seem to have contributed to a lack of recognition that HRA is a field with unique needs, and one that is needed to be developed as a professional field on its own.

Finally, the authors support serious discussion on the idea of developing a professional organization for HRA, proposed by some of our colleagues, in order to build and define this complicated discipline.

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