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COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

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HRA DATA AND RECOMMENDED ACTIONS TO SUPPORT THE COLLECTION AND EXCHANGE OF HRA DATA

CSNI WGRisk Report

September 2008

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full member. NEA membership today consists of 28 OECD member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made of senior scientists and engineers, with broad responsibilities for safety technology and research programmes, and representatives from regulatory authorities. It was set up in 1973 to develop and co-ordinate the activities of the NEA concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations.

The committee's purpose is to foster international co-operation in nuclear safety amongst the OECD member countries. The CSNI's main tasks are to exchange technical information and to promote collaboration between research, development, engineering and regulatory organisations; to review operating experience and the state of knowledge on selected topics of nuclear safety technology and safety assessment; to initiate and conduct programmes to overcome discrepancies, develop improvements and research consensus on technical issues; to promote the co-ordination of work that serve maintaining competence in the nuclear safety matters, including the establishment of joint undertakings.

The committee shall focus primarily on existing power reactors and other nuclear installations; it shall also consider the safety implications of scientific and technical developments of new reactor designs.

In implementing its programme, the CSNI establishes co-operate mechanisms with NEA's Committee on Nuclear Regulatory Activities (CNRA) responsible for the programme of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It also co-operates with NEA's Committee on Radiation Protection and Public Health (CRPPH), NEA's Radioactive Waste Management Committee (RWMC) and the NEA's Nuclear Science Committee (NSC) on matters of common interest.

FOREWORD

As stated in the mandate of CSNI's Working Group on Risk Assessment (WGRisk), the working group supports improved uses of Probabilistic Safety Assessment (PSA) in risk informed regulation and safety management through the analysis of results and the development of perspectives regarding potentially important risk contributors and associated risk-reduction strategies. WGRisk's activities address the PSA methods, tools, and data needed to provide this information.

One of the key areas of uncertainty in current PSA involves Human Reliability Analysis (HRA). WGRisk has been an active forum for information exchange on HRA since the early 1990s. The working group's past efforts have addressed HRA practice and data issues [see NEA/CSNI/R(1998)1] and the development of methods for Errors of Commission [see NEA/CSNI/R(2000)17 and NEA/CSNI/R(2002)3]. In 2004, the working group issued a Topical Opinion Paper on HRA [CSNI Technical Opinion Paper No. 4] that identified the scarcity of empirical human performance data as a significant challenge.

To address this challenge, WGRisk initiated a task to assess the feasibility of a joint effort on HRA data and to define its direction and emphasis. This report presents the results of this work and the basis for its main recommendations to promote increased HRA data collection in simulators and to establish a project for the collection and exchange of HRA data.

In addition to the individuals and organizations listed at the end of the report, whose inputs were invaluable to the task, the Working Group would like to thank B. Kaufer, P. Pyy, and A. Amri of the NEA Secretariat for their support throughout this work.

EXECUTIVE SUMMARY

Background

Probabilistic Safety Assessment (PSA) is today an essential component of regulatory and utility decision-making. Human Reliability Analysis (HRA) provides a crucial set of inputs to PSA and produces insights useful for nuclear power plant safety. An extensive reliance on expert judgment has characterized HRA throughout the development of PSA and contributed to significant uncertainties in the PSA's results. The lack of data on human performance in complex, human-technical systems in general and in nuclear power plant accident scenarios in particular is the main reason for this reliance.

The need for HRA data is acknowledged within the PSA community. Over the years, there have been a number of data collection efforts in the member countries, some of which continue today. There have been efforts to extract HRA-relevant information from operating experience reports and on the basis of simulated accidents. While these efforts have contributed to a better understanding of human performance in nuclear power plants, there are difficulties with the broad use of this data for HRA. The technical difficulties include 1) the strong dependence of human performance on specific aspects of the context, which is an obstacle to aggregating data; 2) the relatively low frequency of significant human errors (at the level of modeling of PSA); and 3) the extent of reporting on key factors.

In the last few years, there have been developments pointing to the potential value of renewing efforts to collect and exchange HRA data. These include: the increased use of PSA in supporting decisions, which places increased demands on the technical basis for the PSA models, including HRA; the emergence of HRA methods to better address the effect of scenario context on human performance and the issue of Errors of Commission; and increased cooperation within the international HRA community aimed at achieving some level of consensus in HRA modeling and applications.

Objective and Scope

In 2002, the Working Group on Risk Assessment (WGRisk) initiated a task to assess the feasibility of a joint effort on HRA data and to define its direction and emphasis. The objectives of the task were to develop a framework for collecting, analyzing and exchanging HRA data and to suggest the next steps that would be needed to establish an OECD project to exchange HRA-related data and information.

This report presents this framework and a set of recommended actions. The basis for the framework and recommendations are based on the task group's examination of HRA data needs, candidate sources of data, and the challenges for collecting and exchanging the data. In view of the active research and developments in HRA, the report presents a snapshot. The follow-on activities recommended in this report are designed to take advantage of results/lessons from on-going HRA activities, including the International HRA Empirical Study at the OECD Halden Reactor Project.

The expected readers of the report are PSA professionals and generalists dealing with risk and safety management.

Approach

The task group addressed the following questions: Recognizing the numerous facets of human performance, what kind of data is needed? What are the potential sources? What actions can be taken? What are the challenges, both technical and non-technical? How can they be addressed? What are the factors for success?

The task group reviewed general trends in HRA applications and the associated data needs. Current HRA data efforts in the member countries were reviewed on the basis of the literature and discussion with national experts and project managers. Existing international programs for the exchange of HRA-related data were also reviewed.

Results and their significance

The task group has identified data collection in nuclear power plant training simulators as well as research simulators as a priority for a future NEA activity in this area. These sources are good candidates for producing new information about human performance during potential accident scenarios. In addition, the operator tasks observable in simulators relate to the category of human failure events that is the most important in terms of risk in current PSA results.

Based on an evaluation of the challenges for the collection of this data and its exchange, recommendations for the next actions are presented. The three main elements of this way forward are: a workshop on simulator data collection, a report on best practices related to the use of simulators in support of PSA, and the establishment of a data project with a core group of participants. To support such a project, a framework for the collection and exchange of data and information is presented.

This framework, together with the proposed workshop and subsequent report on best practices, lays the groundwork for facilitating and coordinating the collection and exchange of a set of data and information that will support HRA applications in PSA as well as the on-going developments of HRA methods.

Specific Findings

- A broad range of sources produce human performance data and information relevant for nuclear power plant HRA. The main sources include events from the operating experience of nuclear power plants, operator training in simulated abnormal and accident situations, and human factors and human-system interface studies. Data from other industries provides valuable additional information but using these involves the added challenges of evaluating their applicability and accounting for the differences in the systems and in the performance conditions.
- There are currently a number of R&D programs that generate HRA-related data or that are developing approaches for collecting or using data for HRA purposes. Although there are a variety of HRA methods and some differences in emphasis, the HRA community has a common understanding of HRA data needs: Data is needed to support HRA analysis and PSA as well as HRA method development activities. Moreover, there is a need to support both the widely used HRA methods and the methods developed during the past 10 years. Developing a program to collect and exchange data from these potential data sources will require significant effort. Given current programs and facilities, some will take more work than others. The proposed framework and the recommended actions consider this.
- Operator performance in the response to abnormal and accident scenarios is an important contributor to plant safety, as shown in the results of current PSAs. Information on these actions in the operating experience is limited because serious incidents and accidents fortunately remain rare events, by

virtue of the high level of safety in nuclear power plants. While this experience is valuable, it does not address most of the post-initiator operator actions in a PSA.

- Data on the operator responses to abnormal events and accidents has to rely mainly on performance in simulated situations. Although plant-specific simulators are widespread, their current use is almost solely for training. A few organisations do have on-going programs of periodic simulator studies dedicated to HRA purposes. Given that simulator time and the time of the operating crews are limited resources, it is important that the experience from previous studies in both training and research simulators is shared. The validity of simulator data and the impact of data collection on the operators in the simulator are issues that need to be addressed. An increased use of simulators to collect data for HRA and the exchange of data depends on the further development and promotion of guidance for this type of use.
- In using HRA data obtained from outside an organisation, an important task is assess the applicability of the data and to take into account the differences between facilities and organisations. The information needed to assess applicability includes the technical features of the facility, automatic control and safety system information, as well as procedures, training, and operational practices. In exchanging most types of HRA data, the protection of proprietary information and the protection of the privacy and anonymity of the concerned individuals are essential issues. Previous experience with NEA data projects suggest appropriate measures to address these.

Conclusions and recommendations for the way forward

The aims of the recommended actions are to: a) facilitate improved use of available data and obtain more value from facilities, b) support increased HRA data collection in plant simulators by sharing methods and good practices, c) provide the basis to establish an HRA Data Collection project and to carry out a pilot effort.

- WGRisk and WGHOF should organize a workshop on the use of simulators for HRA purposes. The workshop should address the methodologies and practices applied in these efforts, how simulator studies for HRA purposes are best carried out, and the benefits that may be expected. Based on the workshop, a report on best practices related to the use of simulators in support of PSA will be produced.
- It is recommended to use the results of the workshop to establish an NEA HRA Data project involving interested organisations. The initial, primary objectives should be to further develop the data exchange framework; to apply the framework in a pilot effort; and to identify and prioritize those areas of human performance in most need of additional data, from the perspectives of both PSA practitioners and the research community. Some of the factors for the success of an HRA Data project are: depth of experience and on-going programs in some member countries, interest in getting added benefits from simulation facilities, and recognition that simulators are an under-developed source of data on post-initiator human performance. Member countries can gain benefits relatively soon from work in this area. However, years of sustained effort will be required to get full benefits. Bootstrapping (e.g., via use of pilot studies) provides a practical approach.
- The review of data needs and sources has highlighted the complementarity of operating experience and simulated emergencies as sources of information and shown that improving the state of HRA data involves a cycle of predictive and retrospective approaches: HRA analysis and prediction of human performance, studying performance in both real events and simulated conditions, and evaluating experience to assess predictions and identify human performance issues. This suggests that WGRisk will also need to work with WGHOF and WGOE to identify ways to make better use of the well-established programs for exchanging operating experience data at the national and international levels, in which regulators, industry and the utilities participate.

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ABBREVIATIONS

AIT	Augmented Inspection Team
ASEP	Accident Sequence Evaluation Program HRA Procedure [NUREG/CR-4772]
CBDT	Cause-based Decision Tree (HRA method)
CNRA	Nuclear Energy Agency Committee on Nuclear Regulatory Activities
CRIEPI	Central Research Institute of Electric Power Industry, Japan
CSN	Consejo de Seguridad Nuclear, Spain
CSNI	Nuclear Energy Agency Committee on the Safety of Nuclear Installations
EDF	Electricité de France
EOC	Error of Commission
FIRE	OECD Fire Data Exchange project
HCR	Human Cognitive Reliability (HRA method)
HEART	Human ErrorAssessment and Reduction Technique (HRA method)
HFE	Human Failure Event
HRA	Human Reliability Analysis
HRP	OECD Halden Reactor Project
ICDE	OECD International Common-Cause Failure Data Exchange project (OECD Data Project)
INES	International Nuclear Event Scale
IRS	Incident Reporting Service
IRSN	Institut de Radioprotection et de Sûreté Nucléaire, France
JNES	Japan Nuclear Energy Safety Organisation
KAERI	Korean Atomic Energy Research Institute
NPP	Nuclear power plant
NRI	Nuclear Research Institute Rez plc, Czech Republic
OE(F)	Operating Experience (Feedback)
OECD	Organisation for Economic Co-Operation and Development
PSA	Probabilistic Safety Assessment, also Probabilistic Risk Assessment (PRA)
THERP	Technique for Human Error Rate Prediction [NUREG/CR-1272]
VEIKI	VEIKI Institute for Electric Power Research, Hungary

1. INTRODUCTION

1.1 Background

Probabilistic Safety Assessment (PSA) is today an essential input to regulatory and utility decision-making. Throughout the development of the role of PSA, Human Reliability Analysis (HRA) has provided an important set of inputs on plant safety and produced useful results.

Initial HRA methods focused on whether the conditions necessary for the success of personnel actions in response to potential accident scenarios were present, for instance, identifying and quantifying the effect of shortcomings in the procedural guidance or the human-machine interface. Examples of such methods include THERP [1], ASEP [2], HEART [3][4], and the Cause-Based Decision Tree [5]. Currently, a new set of HRA methods is emerging to address better the effect of the scenario context on performance and the issue of Errors of Commission.

The lack of data on human performance in complex, technical domains such as nuclear power plants has led to an extensive reliance on expert judgment and contributed to significant uncertainties in the PSA's results [6] [7]. Consequently, after completing tasks on the state of HRA [6] and on the outlook for methods addressing Errors of Commission [8] [9], the Working Group on Risk Assessment (WGRisk) initiated a task to identify the actions it could take to address the issue of HRA data.

1.2 Objective

In 2002, a WGRisk task group was set up to examine HRA data needs, candidate sources of data, and the challenges associated with the collection and exchange of this data. This report presents the findings of this work. These findings underlie a set of recommended actions with the ultimate aim of establishing a project to exchange HRA-related data and information.

The expected readers of the report are PSA professionals and generalists dealing with risk and safety management.

1.3 What was done

The task group addressed the following questions: What kind of data is needed? What are the potential sources? What actions can be taken? What are the challenges and how can they be addressed? What are the factors for success?

The task group reviewed the general trends in HRA applications and the associated data needs. Current activities related to HRA data in the member countries were reviewed on the basis of the literature and discussions with national experts and project managers. Existing international programs for the exchange of HRA-related data were also reviewed.

2. HRA DATA NEEDS

Since the issuance of the Reactor Safety Study [10], the quantity and quality of HRA data has been recognized as a significant source of uncertainty in the Probabilistic Safety Assessments (PSAs) performed in the commercial nuclear power industry. These PSAs are now a part of the standard safety basis of nuclear power plants and are used in many regulatory applications.

Over time, many approaches have been developed and applied to integrate information about human and system performance in assessments of system reliability. Data that are used in human reliability analyses are sparse and applications have become overly reliant upon a few sources or use them outside the scope for which they were originally intended. Further, the failure probability estimates provided in some methods are accompanied by large uncertainty bounds. Taken together these cause the uncertainties associated with results of HRAs to be significant.

In estimating HEPs, most HRA methods account for a variety of determinants. These include the specific kind of action being performed, the kind(s) of resulting errors that may occur, other outcomes associated with performance of the task, as well as the conditions under which performance is postulated to occur and their effects on human performance. Data are needed to perform analyses in order to accurately describe the behavior(s) of interest, to adequately characterize the factors that mediate and may influence the likelihood of certain outcomes, and to thoroughly account for the effects of human performance over a range of postulated contexts. Currently a variety of HRA methods are available and although they agree on many of the central tenets necessary for conducting an HRA, most differ with respect to the specific model of human performance underlying each method. As a result, the activities and specific information needed to support method implementation may be different. Despite such differences, a number of the data needs are similar, owing to similarities of: the power producing systems to which they are applied; the kinds of operations that are routinely performed in nuclear power plants; and the personnel and postulated accident conditions over many nuclear power plants.

In the nuclear industry, some of the major needs for human performance data today include:

- data on decision-making in abnormal and accident scenarios, which is central to analyzing and understanding the risks of scenarios involving errors of commission;
- data related to the ergonomics of computer display-based human-system interfaces;
- data on performance in scenarios with extended time frames, e.g. 6 to 24 or more hours, which may be associated with the slower dynamics of Low Power and Shutdown conditions, of passive systems, and of advanced reactors requiring limited actions by the operators in the short term;
- data on human contributions to latent system failures, associated with maintenance, testing, and return-to-service.

More generally, human performance data is also needed to explore the importance of safety culture and organisational factors.

2.1 Data on operator decision-making

Operator decision-making is an important element of most operator actions modeled in a PSA, encompassing

- the situation assessment (diagnosis and decision) associated with required operator actions,
- situation assessment related to the performance of inappropriate, aggravating actions (“errors of commission”), and
- human failure event dependencies, through cognitive dependence

In addressing all of these, HRA relies almost exclusively on expert judgment, due to the number of factors involved, the interactions among these factors, and the difficulties in setting up “similar” situations for collecting and aggregating data.

Outside of the PSA/HRA applications, the investment of resources has focused on supporting operator decision-making and on the presenting plant information in the control room in ways that allow an overview while highlighting essential, critical information. The transition to symptom-based procedures, in some cases computerized procedures, and the introduction of diagnosis aids are examples of the first. The safety parameter display system, alarm filters, and large overhead displays are examples of the second. While there are data related to the verification and validation of these, these data are not in a form directly usable for HRA. There are no data measuring performance and reliability with these in PRA-like scenarios.

2.2 Data related to performance with computer-based HSIs

Modern, computer-based human-system interfaces (HSIs) have many ergonomic advantages. For instance, they can be animated or colored to show abnormal trends, they can present alternative views to support specific tasks, a large selection of displays can be made available, or the operators can select default layouts according to their preferences and current tasks.

The technical basis for the design of computer-based HSIs is based on human factor studies. Additionally, studies are often carried out for the plant-specific verification and of these interfaces. However, the collection of quantitative human performance data for these HSIs has been limited. For failure modes that have analogies in conventional interfaces, e.g. misreading the value of a plant parameter, the HEPs applicable to conventional interfaces from sources such as the THERP Handbook often continue to be used. In contrast, the failure modes specific to computer-based HSIs have generally not been addressed.

2.3 Data related to performance in extended time frames

Extended time frames refer to scenarios with time windows on the order of hours, from as little as 4-6 hours up to 24 or 48 hours. Time windows of this order arise for

- long-term actions in all types of scenarios (ensuring water supply or heat sink after to maintain the plant in a safe state after it has been brought to a stable safe state)
- scenarios in Low Power and Shutdown conditions, which typically have large water inventories and generally slower dynamics
- plants with passive systems, again with slower dynamics

- advanced reactors requiring limited actions by the operators in the short term
- accident management actions in severe accidents, where a Technical Support Center is assisting or guiding the control room staff

Such scenarios are challenging for the modeling of hardware (systems analysis and accident sequence modeling) as well as for HRA. It is expected that the human performance in these scenarios will be significantly better than for actions that are required in the first hours immediately following an initiating event, due to the time available and the redundancy in staff after the Technical Support Center is constituted and becomes available. These expectations are generally true and current PSAs typically use lower estimates for these human failure events.

On the other hand, there are limited or no data that systematically demonstrate these effects. While many decisions and actions are obviously easier, some precursor events and accidents show that an incomplete or incorrect understanding of the plant state can persist hours into the event, through shift changes. In addition, the technical support center (although technically increasingly better equipped) does continue to rely on the control room crew for information. Finally, there is a potential for error in the communication and coordination between the control room and the technical support center.

2.4 Data on human contributions to latent system failures

Human errors in connection with maintenance, testing, and return-to-service can cause latent system failures and contribute to the unavailability of systems. In this area, HRA focuses primarily on failures that may disable multiple, redundant systems. In terms of methods, the consensus is that the THERP and ASEP methods are for the most part adequate for estimating the probabilities of pre-initiator HFEs. In many cases, the human contribution is assumed to be included in the hardware failure probabilities, that is, in the plant-specific and generic data that are used to estimate hardware failure probabilities. In any case, there have been no major developments of HRA methods for pre-initiator HFEs.

At the same time, latent system failures make up a major proportion of reportable events. As can be seen, for instance, in the data from the International Common Cause Failure Data Exchange (ICDE) project, these latent system failures frequently include a human failure contribution. This contribution can be due to a human failure associated with maintenance and testing, as mentioned, as well as with plant modifications. Consequently, data to quantify the human failure contribution to dependent failures among redundant systems is a concern.

2.5 Data needs addressed by the proposed initiative

The proposed initiative addresses primarily the need for data on operator decision-making in abnormal and accident scenarios. In this area, there is a large, untapped source of data, namely the plant-specific, full-scope simulators that are available for most nuclear power plants in the member countries. The discussion of candidate data sources, the subject of the next chapter, will provide the motivation for this focus.

To a more limited degree, it is expected that the proposed initiative would or could yield some data related to human performance on computer-based HSIs.

The data needs on extended time frames are more difficult to meet. The first reason is that it is difficult to run long-running scenarios in a repeatable way; setting up the context for the action of interest may be difficult given that the actions of the crew may drive the scenario in other directions, changing the context. A second reason, for the long time frames associated with post-accident (post-core melt) response, is that most simulators are not able to simulate the conditions near or after core melt. Finally, long simulator sessions are relatively expensive – typical simulator sessions are on the order of 1-3 hours. Not all extended time frames are subject to these difficulties, sessions can be designed to address the slow dynamics of some of these scenarios, for instance, when they are associated with a large water inventory or a passive system.

Finally, the proposed initiative does not address the human contributions to latent system failures. Data on system failures are to some degree already being collected, in particular for the estimation of hardware failure probabilities. Given interest in the member countries, there could be scope for an HRA-related activity in this area as well.

3. SOURCES OF HRA DATA AND RELEVANT ACTIVITIES

3.1 Overview

The HRA data needs discussed in Chapter 2 relate to human performance in the context of nuclear power plants and to the technical, human performance, and organisational conditions typical for these plants. This chapter focuses on potential sources of nuclear-specific HRA data and on selected relevant activities in the member countries and international organisations.

The activities in member countries that are relevant for HRA data fall into four main categories:

1) collection and analysis of operating experience
2) operator training, in particular in plant simulators
3) studies of human performance / reliability in simulators
4) collection and analysis of HRA data

Another source of information about HRA during accidents or severe accidents is the observation of emergency exercises. These observations fall into the category of simulated situations but are not limited to the control room; such observations may support the HRA for Level 2 PSA, for instance.

It is worth noting that quantitative and qualitative data about the general behavioral tendencies of people and information from other task domains (other industries) can also inform HRA and PSA for nuclear power plants.

3.2 Operating experience

Operating experience is reported and analyzed to assess the effectiveness of technical, human, and organisational safety measures as well as to prevent or avoid that any hardware- or human-related failures that occur are repeated across facilities that share design features, hardware systems or components, procedures, or operational and maintenance practices.

A recent report of the CNRA Working Group on Operating Experience (WGOE), entitled “The Use of International Operating Experience Feedback for Improving Nuclear Safety” [11], presents a review of existing international operating experience feedback (IOEF) processes. This review has been performed with the objective to provide recommendations on how to better organize the international network and outputs for more effective use of the operating experience feedback.

This reporting and sharing of operating experience information occurs at the utility, owners’ groups, national, and international levels.

At the plant level, nuclear power plant organisations log their own experience and review this data internally, providing feedback for operations and training as well as for maintenance. In addition, they often share this information within the owning organisation, for instance, when the utility company owns several nuclear power plants.

Utilities additionally share operating experience data with other utilities that have nuclear power plants from the same vendor, in the various Owners' Groups. Of particular relevance for HRA, many Owners' Groups provide utilities with a base version of abnormal and emergency operating procedures and review the experience with these procedures in a continuous improvement process.

At the national level, operating experience events exceeding defined levels of severity must usually be reported to the regulatory authorities, together with an analysis of the event, the lessons learned, and any measures identified to prevent their re-occurrence or to mitigate their consequences.

At the international level, incidents and accident events are reported to the International Atomic Energy Agency (IAEA) and OECD/NEA in the Incident Reporting System (IRS). The main objective of the IRS is to assure proper feedback on events of safety significance on a worldwide basis, in order to help prevent the occurrence or recurrence of serious incidents or accidents. These agencies also use the International Nuclear Event Scale (INES), in conjunction with the Nuclear Events Web-based System (NEWS) for rapid communication to the media and the public regarding the safety significance of events at all nuclear installations associated with the civil nuclear industry.

Finally, the utilities in many countries additionally share operating experience in the programs of industry groups that extend beyond the Owners' Groups. U.S. utilities participate in the operating experience feedback program run by the Institute for Nuclear Power Operations (INPO). An analogous program at the international level is run by the World Association of Nuclear Operators (WANO) for the use of its member organisations.

The operating experience programs make up multiple feedback loops. To accomplish the aims of these programs, the event reports that are shared are evaluated at each nuclear power plant in terms of the applicability of the reported issues and of the adequate response to these issues.

More detailed information on these programs is presented in the above-mentioned report of the CNRA Working Group on Operating Experience (WGOE) [11].

Observations on operational experience feedback programs

Operating experience is a highly relevant source for generating human reliability information since it comes from the environment that HRA analyses are treating and includes the variables that affect human performance in that environment. It may significantly help in the identification of the relevant human failure modes.

Human contributions to the latent failures of systems and components make up a dominant proportion of the human errors reported in operating experience reports. An analysis of significant U.S. operating events with human failure contributions showed that latent human failure events were present in every operating event analyzed and outnumbered active errors by a ratio of 4 to 1 [12]. In summary, the information collected and exchanged within OEF programs relates primarily to latent human failure events.

For the other data needs discussed in Chapter 2, on decision-making, on the ergonomics of computer display-based HSIs, and on human performance in extended time frame scenarios, operational experience delivers comparatively little data.

Noting that this data mostly relates to latent system failures or, in HRA terms, to pre-initiator actions, more work is needed to develop approaches to extract the relevant information and methods to incorporate this information into HRA. Efforts in this direction include HERA [13] (cf. Section 3.5) and the development of Bayesian methods [14].

3.3 Operator training in simulators

At many nuclear power plants, the response to abnormal and accident scenarios is trained in plant-specific training simulators. Although precursor events and the relatively rare accident events can be used as a source of information concerning this area of operator performance, the primary source of potential HRA data for this area remains simulators.

First, the low frequency of actual events and the highly specific circumstances that usually characterize actual events occur means that these events tend to be more suited for assessing whether the human performance models used in HRA are adequate than for informing HRA quantification. In other words, actual events are used mainly to assess whether HRA models address the aspects that arise in these events. Secondly, training simulators have two major advantages as a source of HRA data. One is that the conditions for the operator response can be controlled. The second is that the scenarios can be repeated for a set of crews, which means that the systematic aspects of the response may be better distinguished from those that are unique to the realization of a scenario or to a crew.

Despite these advantages, the potential for HRA data from training simulators is today largely unexploited. There are a few programs in member countries, which are discussed next, in Section 3.4. Some of the reasons for the unexploited potential include:

- A shortage of simulator time and crews for simulator studies that are not directly dedicated to training. In addition, the scenario may be tailored for training goals adapted to each specific crew.
- The cost and learning curve for effective HRA-specific studies. To collect HRA data that is useful for the longer term, HRA-specific simulator studies have to be carefully designed, the evolution of the session has to be carefully monitored and controlled, and the raw data that is collected has to be analyzed.

It is worth noting that EDF in France and the utilities participating in the Halden Reactor Project studies have indicated that HRA-specific studies are of value for operator training, even if they are typically run differently from training sessions. (For instance, HRA-specific studies generally avoid interrupting the simulation and they strive to make the scenario as similar as possible for all the crews. In contrast, training sessions may be suspended in order to discuss a particular phase of the scenario in the “heat of the moment” and subsequently resumed.) In addition, some programs do collect HRA data in simulator sessions whose primary aim is operator training.

Other remarks

Training simulators could also deliver data on the ergonomics of computer display-based interfaces because they strive to replicate the actual control room faithfully and comprehensively.

There tends to be less experience in training simulators for scenarios with extended time frames. Practical considerations with regard to the duration of the simulator sessions are one main reason. Another reason is that, if the extended time frames relate to more degraded plant conditions, the scenario may be difficult to “set up” in the simulator, meaning that the prior hardware and human failure events may be difficult to create in a credible way. Finally, training simulators may be limited in terms of simulating plant conditions near and beyond core damage.

3.4 Studies of human performance and HRA data collection in simulators

Plant simulators possess high fidelity in replicating the physical appearance and behavior of nuclear plant systems. In nearly all cases, they are identical to the control rooms of the actual plants and provide the best approximation of the operating context for control room activities and responses. Simulators also have data logging facilities for recording system actions, human actions and control inputs, plant parameter values, and most also provide for the ability to produce high quality audio and video recordings of crew interaction. Since they are used to train and license operators, they are also familiar to crews and are likely to produce behavior that is representative for many PSA-relevant conditions. At the same time, the analysis of the simulator data needs to take into consideration the differences between real and simulated situations and the impacts these may have on the observed responses.

As noted in the discussion of training simulators, a few member countries have on-going programs in which simulators are being used for HRA purposes. In addition, there have been notable programs in the past in some countries. Finally, the OECD Halden Reactor Project carries out HRA studies in the Hammlab experimental simulator facility.

Table 3.1. Overview of simulator study types for HRA data collection

	NPP training simulators	Experimental simulators (e.g. HRP's Hammlab)
HRA-relevant data derived from training sessions	x	
HRA data collection during training sessions	x	
Sessions dedicated to HRA data collection	x (1)	x
Human-system interface validation studies (2)	x	x

(1) It is worth noting that simulator sessions dedicated to HRA data collection can be valuable for training.

(2) HSI validation studies may tend to provide more qualitative information, e.g. impact of HSI on mode of response, way of working.

Table 3.2 presents an overview of these programs, based on information provided by WGRisk representatives and/or in the reports on PSA developments in member countries, from a 2005 Halden workshop [15], and the literature.

It can be seen that the use of simulators for HRA falls into two broad categories.

1. **Collection of timing-related data.** A number of the programs collect timing-related data, which are then used together with Time Reliability Curves (TRCs) to derive plant-specific HEPs. Although several TRC methodologies are available and remain generally accepted, there is a growing recognition that there are important limitations to this approach in covering the reliability of operator decision-making. A number of more recent HRA methods do not use available time as the main driver of the decision element of HEPs.

It is worth noting that aside from their use for deriving HEPs, plant-specific and scenario-specific timing-related data are useful inputs for realistically modeling the dynamics of post-initiator operator responses in PRA.

2. **Collection of qualitative inputs for HRA.** A large amount of qualitative information is produced in simulating design basis accidents and beyond-design-basis accidents in training simulators and in observing the operator responses. Examples of this qualitative information includes, as can be seen in the table, the observation of:
   - how emergency procedures are applied in the scenarios
   - the areas in which these procedures are difficult to use or error-prone
   - operating styles and crew teamwork
   - the effect of context, including intended and unintended effects of trained rules and priorities.

Table 3.2. HRA data collection efforts in simulators in member countries

Organisation	Dates	Description
EDF, France	1984 - present	Since 1984, in a series of campaigns, information and data have been collected in over 300 simulator sessions. These include sessions dedicated to HRA data collection as well as operator training sessions. In the 2003-2007 campaign, there were 57 observations of simulator sessions. The observations are performed to collect information on the application of Emergency Operating Procedures and on contextual information, in support of the application of the MERMOS HRA methodology. See Appendix B for a breakdown of the observations in terms of objectives.
Paks NPP and VEIKI, Hungary	1992-2006	The observations made at the simulator centre of the Paks NPP included collection of both timing-related data and collection of qualitative inputs for HRA with more and more focus on the latter. Earlier studies in 1992 were carried out using a methodology derived from EPRI's Operator Reliability Experiments (ORE). Completely revised data collection taxonomies, methods and tools were applied in subsequent simulator sessions in 1995 and in 2004. The latest HRA-purpose observations were carried out in 2004 to investigate changes in effectiveness of crew performance following the implementation of new, symptom-oriented procedures at Paks in 2003.
JNES, Japan	2005 - present	JNES launched projects aiming at the development of guidelines for collecting HRA data using plant simulators - 2005- 2007. Experiments were designed in accordance with the guidelines and conducted at BWR training centers – 2006-2007. The guidelines appeared to be useful with no critical deficiency. Therefore no fundamental modifications were made to the draft guidelines.

Organisation	Dates	Description
Central Research Institute of Electric Power Industry (CRIEPI), Japan	2003 - present	CRIEPI has a program to enhance NPPs operating team performance. In this program, a method to evaluate team work has been being developed in cooperation with operator training centers and utilities operating teams. This method was applied to evaluate team work of utilities' teams facing abnormal operating conditions such as LOCA, etc., and found that this method shows reasonable results.
KAERI, Korea	2000 – present	The OPERA database (Human Performance Database for Operator Performance and Reliability Analysis) is an effort aimed at identifying and understanding the main sources of problems related to human performance. It includes data from reactor trip events as well as NPP emergency scenarios simulated in training simulators. To date, 160 simulator training sessions have been analyzed in terms of error modes, associated cognitive functions, response time data such as event diagnosis and task execution, and the use of procedures in emergency scenarios.
NRI, Czech Republic	1998-2000	Approximately 90 training sessions (related to PSA scenarios) were observed and analyzed in three series of exercises. The main focus was put upon development of symptom based procedures, but an important additional goal was analysis of crew reliability. Every scenario was split into segments described by several characteristics - complexity, length, formal structure (ergonomics), action performer (primary versus secondary circuit operator), risk importance, type of action, simulation quality. Correlations between characteristics levels (simple versus complex step) and crew work quality and reliability marked with four grades were searched for. In addition, several (12) HEPs derived for the purpose of plant PSA by generic methods (decision trees) were modified on the base of training observations.
Slovenia nuclear regulatory authority	2005-2006	Response times for a set of actions have been measured, in support of a Time Reliability Correlation model.
OECD Halden Reactor Project	1994 – present 2006-2007	Since 1994, the HRP has performed a series of experimental studies in the Hammlab simulator facility to collect data relevant for HRA. Most of these studies have focused on specific performance shaping factors and their effects on performance. Since 2006, the HRP is a key contributor to the International HRA Empirical Study [16-18], in which data on the performance of operators in PSA-based scenarios are being collected in a simulator study and compared to predictive HRA analyses.

3.5 Collection of HRA data from sources other than simulators

Adding to the description of efforts to collect HRA data in simulators presented above in Table 3.2, this section describes a number of HRA data collection efforts from sources other than simulators. These are summarized in Table 3.3.

Table 3.3. HRA data collection efforts from sources other than simulators

Program	Source	Description
CORE-DATA, UK	operational data on specific tasks in various industries, supplemented by expert judgment	This database contains more than 400 Human Error Probabilities from a range of industries, including nuclear power and reprocessing; chemical industry; offshore platform drilling and evacuation; service industry; air traffic management; and some defence-related data, etc. For each of the data points, there is a description of the error, its context, and any performance shaping factors. Where possible, the actual number of errors and the number of opportunities for error, which together enabled the HEP to be calculated, are given in the database. The database itself contains a large amount of real (i.e. operationally-recorded) data, as well as some HEPs that contain a mixture of such data and expert judgment.
HFEG/JNES human error event database, Japan	Voluntary and required event reports	The Human Factors Evaluation Group (HFEG) in JNES has accumulated accident and trouble events which utilities reported to Ministry of Economy, Trade and Industry according to laws or voluntarily and produced an associated database. This program is a continuation of work by the Institute of Human Factors of NUPEC. HFEG has developed methodologies of systematically analyzing these events from the view point of human factor. Using these methodologies, HFEG has analyzed these events to make human error event database. 257 events which occurred from 1966 to 2006 are stored in the database. Human errors events have been analyzed and evaluated systematically from the view points of error causes, human error mechanisms and error modes, taking into account contents of work.
CRIEPI Human Factors Database, Japan	Operating experience events	The Human Factors Research Center (HFC) in CRIEPI has programs to enhance safety and reliability of nuclear power operations. Since its establishment in 1987, HFC analyzed, in cooperation with Japanese utilities, human errors happened in Japanese NPPs with a systematic technique named HINT/J-HPES (advanced version of J-HPES) to find their latent factors and countermeasures. The data are stored Human Factors Data Base in CRIEPI to share them among the utilities. Using the data, HFC is publishing booklets and posters to share the lessons-learned and also analyzing statistically the relations between types of human errors and their latent factors.

Program	Source	Description
HERA, US *	LERs, AITs, and other operating event; simulator data	The objective of the Human Event Repository and Analysis (HERA) System [13] is to make available empirical and experimental human performance data, from commercial nuclear power plants (NPPs) and other related technologies, in a content and format suitable to human reliability analysis (HRA) and human factors practitioners. The framework is intended to be suitable for collecting human performance data from operating events as well as simulator data. Over 45 operating experience (reportable) events, each including several human events, have been analyzed based on Licensee Event Reports and other sources of information. In addition, data from Halden simulator experiments are also being incorporated into HERA [19]
OPERA, KAERI, Korea *	Reactor trip events; simulator data (see Table 3.2)	KAERI's Human Performance Database for Operator Performance and Reliability Analysis (OPERA) includes HRA-related data from simulator training sessions on NPP emergency scenarios (see Table 3.2) as well as reactor trip events. Over 100 human-related reactor trips have been analyzed and included in OPERA.
ICDE data project, OECD NEA	Reported common-cause failure events	The data collected in the OECD International Common-Cause Failure Data Exchange (ICDE) project includes data on human contributions to common-cause events. This data has not been generally been applied to support HRA analysis; however, it represents a useful source of information on human failure events that may be relevant to HRA.

More detailed information and references are provided in Appendix B, "Selected Data Collection Efforts".

4. ISSUES AND CHALLENGES

There are three major issues for the collection and exchange of HRA data. These are:

1. Confidentiality and privacy issues
2. Providing information to allow the applicability of the data to be assessed
3. Workload associated with data collection

This section discusses these challenges and some solutions that may be used in the proposed data initiative to address these.

4.1 Confidentiality and privacy

Data related to human performance must be treated confidentially because it deals with the performance of individuals whose privacy must be respected. Confidentiality and privacy is frequently not only a matter of policy but also a legal requirement.

The main way to deal with confidentiality and privacy is to anonymize the data, by removing information that may be used to identify the individuals and crews involved. For derived and analyzed data, as opposed to raw data including video recordings, this is not an issue since the PSA and HRA are concerned with the performance of representative crews and some general variability among these crews rather than with the performance of specific crews.

If video recordings are essential, for instance, to capturing the essence of a miscommunication that may not be as recognizable from a transcript, there are technical means available for ensuring privacy although these may be relatively expensive (today).

A second level of confidentiality concerns the identification of the facility from which the data comes. In general, the identification of the facility does not affect the applicability of the data. On the other hand, some of the information that is provided to ensure applicability, for instance, a detailed description of the plant, may make it possible to identify the facility, which is in some cases a sensitive matter. Unlike privacy-related issues, this level of confidentiality may be addressed by restricting access to the data.

In summary, confidentiality and privacy are important issues that must be addressed systematically addressed in a data exchange program. The measures in place to ensure confidentiality and privacy are critical to the willingness of the utility and operator organisations to agree to the exchange of data.

4.2 Applicability of the data

For HRA data to be useful for organisations other than the utility where this data is collected, the potential users of the data must be able to assess the applicability of the HRA data to their environment. At a second level, they must be able to understand the environment within which the data has been collected in order to make appropriate adjustments.

The performance environment, or in human factors terms, the performance context is generally thought to include at least the following:

- the plant profile in technical terms (type of plant, plant technical systems and automatic control and safety system features)
- the procedures and other formal, explicit operational strategies and rules addressed in training, etc.
- the organisation of the crew (number of crew, their responsibilities, and roles)
- performance practices, norms of behavior and response, and other informal rules

Most of this information is standard and fairly accessible. For instance, some of it is documented in the Final Safety Analysis Report and in other sources. In contrast, attention to formal and informal performance practices and norms is more recent, especially in comparative terms. As a result, the characterization of these practices and norms is a subject of research and is evolving.

For HRA data collection, the main challenge is to make this information accessible and to link it to the data "points". It appears that this challenge can be addressed by an appropriate organisation of the data exchange program.

Another challenge is that this information on the performance context may make it possible to identify a specific facility, which can be a sensitive matter, as noted under Confidentiality and Privacy.

4.3 Workload associated with HRA data collection

It is important to recognize that an HRA data collection and exchange program would co-exist with numerous on-going data-related efforts, including the numerous operational experience feedback programs mentioned in Chapter 3. In this light, the benefits from HRA data exchange should compensate for the workload associated with HRA data collection.

The proposed data initiative addresses this issue by ensuring that the data collected for HRA is exchanged in a form that is directly (or with minimal effort) useful for training and operations.

5. THE PROPOSED FRAMEWORK FOR HRA DATA COLLECTION AND EXCHANGE

The proposed framework for the collection and exchange of HRA data includes two main elements: 1) what data would be exchanged and 2) how the data collection and exchange could be organized. This chapter describes these elements and discusses how the issues identified in Chapter 4 are addressed.

The principal aim of presenting this framework in this report is to provide a suitable basis for setting a data exchange "project" and the associated agreements.

5.1 Data to be collected and exchanged

5.1.1 Focus on HRA data collected in simulator facilities

The proposed framework focuses on data on operator performance in simulated abnormal and emergency situations, collected in simulator facilities. This data addresses HRA needs on decision-making performance. These HRA data needs relate to the modeling of diagnosis and decision-making performance, an area of HRA agreed to be subject to significant uncertainties, and more specifically to the resolution of the issue of errors of commission.

In developing the proposed framework, the full-scope simulators used for training at nuclear power plants have been considered the primary source. Other simulator facilities may also be used to collect HRA data. Within the OECD context, the Hammlab research simulator of the Halden Reactor Project has been used in a series of studies that address HRA issues.

Similarly, simulator sessions dedicated to collecting HRA data are envisioned as the main source of data. However, HRA data may be collected within simulator sessions intended for other purposes, such as training, operator qualification, verification and validation of HSIs, or controlled studies aimed at evaluating the effects or relationships of specific aspects of the operating context on human performance.

As a source for HRA data, simulators may also be used to obtain data on the ergonomics of HSIs that include computer display. While there are technical issues to resolve (e.g., simulator scope), data on performance in extended time frame scenarios may in principle also be obtained in simulators. These applications of simulators for HRA data are not addressed in the current initiative.

5.1.2 Structure of the exchanged data

The data of interest to be collected in simulator studies does not focus uniquely on failure data. Instead, a range of qualitative observations and results are of interest, including observed difficulties, successful performance, recoveries, crew response strategies, and the impact of specific performance factors.

Table 5.1 presents a preliminary structure for a data record, which indicates the general types of desired information. This structure is to be further developed at the proposed workshop.

Observations on the data structure

- The information to be shared and exchanged will consist primarily of the HRA-relevant insights and results obtained in the simulator studies. The potential users (receivers) of this information will need to evaluate its applicability and transferability. For this reason, the insights and results need to be accompanied by additional information concerning the simulator study in which they were obtained. This information would also support the replication of a study for a different nuclear power plant.
- The data structure includes a substantial amount of qualitative data that is needed to understand how the crews performed on the defined scenario. This qualitative data includes for instance the relation between observations and training staff expectations on the operator responses and actions as well as on the procedural paths.
- The timing data is primarily intended to represent the dynamics of the scenario for the purpose of scenario understanding and scenario modeling. It is in any case plant-specific and, as such, is not generally regarded as useful without the qualitative information.
- While a data record may represent the performance of a single crew, reporting the performances of a set of crews would be particularly useful because it shows the extent to which the performance and actions are due to systematic vs. aleatory factors. This represents one of the strengths of simulator data although reports on a single crew’s performance would nevertheless be useful because of the very low frequencies of most abnormal and emergency scenarios, design basis accidents, and beyond-design-basis accidents.
- The data on “observed difficulties and their resolution” provides information on the challenges associated with specific scenarios and on relevant contextual effects and mechanisms that may be considered in HRA predictive analyses.
- Beyond its use to support HRA, this data would be directly useful for training and operations and for developing and improving emergency operating procedures.
- The database of scenarios simulated at other plants, including the expectations of the plant training staff, may be a useful input to the training program at a given plant.
- An important reduction of the workload for the data collection program would be to establish the plant profile data in advance so that it does not have to be reported for each data record.

Table 5.1. Structure of the exchanged data

HRA Data Framework (data content)	Remarks
Scenario information – initiating event, – hardware failures, – alarms, key plant indications, – other events (automatic and safety system actuations), and – their timing	This information is the primary key for indexing the data.
Procedural paths – general, expected procedural path – observed procedural paths	
Key operator responses and actions – responses, actions and their timing – relation to PSA model and training staff expectations	
Observed difficulties and their resolution – phase of the scenario, affected part of the observed response, – how the difficulties were resolved, if resolved	A data record may represent the performance of a single crew or that of a set of crews.
Safety-related insights resulting from the study (in addition to observed difficulties) – related to human performance – related to the scenario, the interaction of operator response and scenario evolution, including scenario-specific "strong contexts"	
Plant profile data – the plant profile in technical terms (type of plant, plant technical systems and automatic control and safety system features) – the procedures and other formal, explicit operational strategies and rules addressed in training, etc. – the organisation of the crew (number of crew, their responsibilities, and roles) – performance practices, norms of behavior and response, and other informal rules (also referred to as operational culture)	This information is needed to characterize the performance context but is generally not scenario-dependent.

5.1.3 Examples of specific data needs related to decision-making performance

Although some of the data needs may be method-specific, most methods will have common needs for data. These include data related to the expected sequence of actions for the given conditions – sometimes referred to as the base case or nominal case human action sequence. Since human performance, even under normal conditions, is variable and further, that conditions exert an influence on performance, data are also needed to identify and characterize potential instances of unexpected human performance. Variously termed in different HRA methods, these include data that may be used to explain or predict cognitive failures of the type that account for the development of inappropriate goals, action plans, and the tendency to persist in their implementation even when contradicted by observation. Data are also needed regarding the effects of unexpected control response and other unexpected phenomena on human performance, and on the development of and potential human response to confusing conditions. These data are needed to support bounding the range of potential conditions and characterizing events that deviate from the expected or base case scenarios.

Response to post-initiating event sequences occurs within a team context as crews of operational staff conduct them. The resources of the crew play an important role in event mitigation. To properly account for and give credit to crew responses, data are needed regarding the practices of plant staff and their performance as teams or crews in coping with an event. Of particular interest is the quality of crew response – that is how well they are able to match performance to the demands of an event. To best characterize such aspects of crew response, data are needed regarding the needs for and performance of crews in communicating information with one another, the kinds of interactions among members that may be expected or may occur, and how they are trained to behave as a team during PSA-related events. Data are also needed regarding how crews use station resources to manage their response to an event. Useful information includes data related to how crews employ procedures in a variety of situations, typical means and approaches used to interface with and control systems, approaches that may be employed when mismatches occur between a crew's expected response and plant conditions, and performance conditions and expected performance over the entire course of PSA-relevant events.

5.2 Organisational framework for HRA data collection and exchange

5.2.1 Data project

The organisational structure for HRA data collection and exchange may follow the approach used in the existing NEA data exchange projects, for instance, the ICDE project for common-cause failure data and the OECD Fire Data Exchange (FIRE) project.

In these data projects, data is accessible to the project members. Membership in the HRA data project would be contingent on contributions of data or in-kind contributions. Some objectives of the proposed HRA data project are discussed next. To ensure the quality of the data, the HRA data project would include a Data Review Group, discussed in Section 5.2.3.

5.2.2 Objectives of the HRA data exchange project

The objectives of a proposed HRA data exchange project could include:

- establishing a common HRA data collection methodology
- sharing and consolidation of HRA data
- support increased collection of HRA data in simulators
- provide inputs to prioritization of human performance issues and scenarios to examine in simulator studies

The intent of the HRA data is to support HRA methods in general, rather than a particular set of methods. It would support HRA applications (analyses) by informing scenario development and identifying factors and other scenario-specific issues to treat in an HRA qualitative analysis.

The HRA data exchange project would contribute to the consolidation of data and to progress on HRA issues, analyzing the data to draw overall findings and lessons. A common methodology for HRA data collection would be needed to support the analysis and aggregation of data and allow comparisons to be performed.

It would support an increase in HRA data collection activities in simulators through the exchange of information on the methodologies for carrying out simulator studies, facilitating the start of such studies in a broader set of nuclear power plant organisations. The exchange of information on the simulator scenarios would provide a selection of ready-made scenarios that have been "tested" elsewhere, for the benefit of experienced organisations as well as newcomers to this area of activity.

Finally, the project may contribute to progress on HRA issues by recommending scenarios and human performance issues to examine, providing common directions for concerted HRA data collection.

5.2.3 Data review group

The main function of the data review group is to ensure database quality. It accomplishes this function by:

- providing guidance for simulator study methodology and for the reporting of the data
- reviewing the submitted data with respect to the data structure and in terms of clarity
- assessing the relevance of HRA data collected within studies intended for other purposes

The data review group's tasks would be performed at regular intervals. In addition, the data review group performs the analyses of the data in support of the objectives discussed in Section 5.2.2.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Findings

- Although there are a variety of HRA methods and some differences in emphasis, there is a common understanding of what HRA data are needed within the HRA community.
    - Data is needed to support both HRA analysis and PSA applications (identification of Human Failure Events, quantification), and HRA method development activities. These developments relate to the issue of Errors of Commission and to improved guidance for HRA practitioners (analysts).
    - Different HRA methods will be appropriate given the scope and objectives of the probabilistic analysis in which they are used. As a result, there is a need to support both the widely used, existing HRA methods and the methods developed during the past 10 years.
- Developing the collection and exchange of data from all of these opportunities will require significant efforts. Given current programs and facilities, some will take more work than others. The proposed framework and the recommended actions consider this.
- There are a number of HRA R&D programs that currently generate HRA-related data or that are developing approaches for collecting or using data for HRA purposes. The report has discussed some examples from France (at EDF), Korea (at KAERI), the U.K. (CORE-DATA), and the U.S. (the Human Event Repository and Analysis (HERA) program. These programs generate information that could be valuable to an international data exchange program, for instance, regarding what practically can be measured/collected. However, these are not aimed at this time at developing an international data exchange program. They use different approaches for data collection and review and they produce data in different formats and at various levels of detail.
- Human performance in the response to plant disturbances (to initiating events) is an important contributor to plant safety, as shown in the results of current PSAs. At the same time, the need for human performance data is more acute for this category of human performance than for pre-initiator performance.
- The task group recommends that the data collection and exchange effort focuses on simulator data, at least initially. The rationale includes:
    - Operational experience – Both at the national and international levels, there are already programs in place for operational experience feedback. While these efforts do produce information useful for HRA, a duplication of the existing efforts should be avoided (Incident Reporting Service, WANO experience feedback, Owners' Groups programs). At the same time, modifying these programs to accommodate HRA requirements will be difficult.
    - There are no efforts on exchanging simulator data. Simulator data has the significant advantage that it can reveal how a range of crews react to a given scenario or set of

scenarios. Consequently, it can show how significant an effect may be (is it one crew or half of the crews that behave a certain way).

- Experience in member countries. There is significant experience in some member countries in performing simulator studies. These studies are quite resource-intensive and the sharing of this experience (as well as the data) may be a significant help to other member countries.
- Owners of data (utilities). There is an interest among utilities to use their simulator facilities to support their PSA studies. The methods for using simulator data for HRA that are available today are not widely used. The guidance to be developed as part of the HRA data exchange project would address the collection as well as the use of simulator data and could lead to a consensus approach that should have increased acceptance.

- Operational experience tends to provide primarily information on human performance related to maintenance, testing, and the associated latent system failures. Improving the state of HRA data ultimately involves using performance data from both real and simulated conditions, i.e. operating experience and simulators.
- Nuclear power plant training simulators as well as research simulators are the main sources of data concerning human performance in response to initiating events. Although precursor events are systematically analyzed and the reports exchanged, this information is more anecdotal and incomplete because serious incidents and accidents fortunately remain rare events, given the generally high level of safety in nuclear power plants.
- Although plant-specific nuclear power plants simulators are widespread, their use is almost completely dedicated to training. A few organisations do have on-going programs of periodic simulator studies dedicated to HRA purposes.
- This experience is a pertinent source of information for newcomers to simulator studies for HRA purposes, for whom the methodology represents significant challenges. These range the design of the scenarios, the selection of raw on-line and post-session data to be collected, to the analysis of this data to obtain the HRA-relevant results. An increased use of plant simulators to collect data for HRA in depends on further development and promotion of guidelines for this type of use.
- Simulator time and the time of the operating crews are limited resources for plant organisations, motivating the sharing of experience. Simulator studies typically involve a substantial effort and the participation of diverse groups. Consequently, it would be important that the experience from previous studies is also shared, in order to maximize the benefits from each new study for the utility as well as for the community.
- In using HRA data obtained from outside an organisation, an important task is to assess the applicability of the data. The information needed to assess applicability includes the technical features of the facility, automatic control and safety system information, as well as procedures, training, and operational practices. More generally, this information is needed to interpret the data and to take into account the differences between facilities and organisations.
- In providing this essential information, the protection of proprietary information and the protection of the privacy and anonymity of the concerned individuals is a challenge for the exchange of many types of HRA data.

6.2 The way forward

The aims of the recommended actions are to: a) facilitate improved use of available data and facilities, b) support increased HRA data collection in plant simulators by sharing methods and good practices, c) provide the basis to establish an HRA Data Collection project to and carry out a pilot effort.

The recommended actions include

a) A workshop on "Simulator Studies for HRA Purposes" and the preparation of a report on good practices and experiences with these studies.

b) Steps to establish an HRA Data Project

6.3 Workshop "Simulator studies for HRA purposes"

Workshops have been held in the past on training applications of the plant simulators; the last workshop in Chattanooga. The NEA published "The Role of Simulators in Operator Training" (CSNI R97/13/1).

The scope of the proposed workshop is the application of simulators in support of HRA. It would address how simulator studies for HRA purposes are best carried out and the benefits that may be expected. The objectives of the workshop would be:

- to present the methodologies and practices for the use of simulators for HRA,
- to review and compare the international experience related to these efforts, and
- to compile suggestions and recommendations for designing and carrying out future studies.

The workshop is intended to benefit both the organisations that are currently collecting and using the HRA data obtained in simulators as well as those looking to initiate such activities. Contributions from industry (utilities) as well as research organisations are anticipated.

In addition to obtaining technical inputs for the proposed framework for data exchange, the workshop would also provide an opportunity to invite potential interested organisations to participate in the proposed HRA data collection and exchange framework

Based on the workshop, a report documenting these good practices and methods would help organisations interested in setting up simulator studies in support of their HRAs, reducing the steepness of the learning curve. To the extent possible, it would capture the consensus on study methodologies and help to ensure that the results of the studies are useful and of the highest quality possible for the performing organisation as well as for the nuclear community. A key function of the report is to ensure that the experiences of organisations that perform this type of study for the first time are positive.

6.4 Establishing an HRA Data Project (agreements and infrastructure)

The establishment of an HRA Data Project will provide a focal point for a joint effort on HRA data.

The starting group of participants would have as initial objectives the further development of the data exchange framework, in technical content and organisational terms, and its application in a pilot effort.

This core group, presumably a minimum of 3-4 organisations, would best be positioned to develop the specific terms of the agreements. The OECD experience with the data exchanges such as those for common cause failure data (ICDE), piping failure (OPDE), and fire (FIRE) will provide a template for the organisation of the HRA information exchange.

Previous experience with NEA data projects shows that with the appropriate measures in place, the challenges related to protecting the privacy and anonymity of the individuals participating in the simulator studies and to protecting proprietary information can be addressed.

A further function of an HRA Data project would be to identify and prioritize those areas of human performance in most need of additional data, from the perspectives of both PSA practitioners and the research community. These are expected to provide inputs to scenario design as well as to the selection of the personnel behaviors and performance factors to be examined.

6.5 Outlook

Some factors for success include:

- **Experience in member countries**. There is significant experience in some member countries in performing simulator studies for HRA purposes. Such studies are quite resource-intensive and the sharing of this experience (as well as the data) may be a significant help to other member countries.

- Owners of data (utilities). There is an **interest among utilities to use their simulator facilities to support their PSA**. The methods for using simulator data for HRA that are available today are not widely used. The guidance developed as part of the Framework would address the collection as well as the use of simulator data and represent a consensus approach that should have increased acceptance.

- **A substantial interest in joint efforts on HRA and HRA data**. The strong and diverse participation in the International HRA Empirical Study (2006-2009), which addresses many of the same challenges confronting HRA data collection, is indicative of this interest. This effort is coordinated by the OECD Halden Reactor Project, with the leadership and participation of regulators, utilities and research organisations from 10 member countries. Its focus on the evaluation of HRA methods based on simulator data makes it closely related to the proposed data framework. Its objective is to evaluate HRA methods by comparing the findings obtained in a specific set of Hammlab experiments with the outcomes predicted in HRA analyses.

Member countries can gain benefits relatively soon from work in this area. However, years of sustained effort will be required to get full benefits. Bootstrapping (e.g., via use of pilot studies) provides a practical approach.

The review of data needs and sources has shown that improving the state of HRA data involves a cycle of predictive and retrospective approaches: HRA analysis and prediction of human performance, studying performance in real and simulated conditions (e.g. events and simulators), and evaluating experience to assess predictions and identify human performance issues. This suggests that WGRisk will also need to work with WGHOF and WGOE to identify ways to make better use of the well-established programs for exchanging operating experience data at the national and international levels, in which regulators, industry and the utilities participate.

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APPENDIX A. EXCHANGES OF OPERATING EXPERIENCE DATA RELEVANT TO HUMAN PERFORMANCE

The major programs for the exchange of operating experience data for commercial nuclear power plants are listed in Table A.1. This data generally includes an analysis of human contributions to the events.

Table A.1. List of major exchanges of OE data

International Program	Organisation(s)	Purpose
IRS – Incident Reporting System	IAEA and OECD/NEA	Operating experience feedback
INES – International Nuclear Event Scale	IAEA and OECD/NEA	Rapid communication to media and public on safety significance of events
INPO	Institute of Nuclear Power Operations (INPO)	Operating experience feedback (national, restricted to member organisations)
WANO	World Association of Nuclear Operators (WANO)	Operating experience feedback (international, restricted to member organisations)
ICDE – International Common Cause Data Exchange	OECD Nuclear Energy Agency	Collection of common-cause failure event data

For information on national Operating Experience Feedback Systems, see App. A of [11].

APPENDIX B. SELECTED DATA COLLECTION EFFORTS

The descriptions of the efforts provided in this appendix are based on country reports to WGRisk, on information available from recent meetings and the literature, and on contributions from WGRisk members.

These include not only data collection in simulators for HRA purposes but more generally efforts that produce data relevant to HRA.

France – EDF

The collection of HRA data in simulators has supported HRA analyses and the development of methods since 1984. Table B.1 lists the various campaigns and their objectives, which are described in a forthcoming conference paper (see the table note for the citation). This paper discusses the benefits of HRA data collection for EDF, the limitations and potential biases associated with this data. It describes the methodology developed at EDF for data collection, including the measures taken to limit the effect of the biases.

Table B.1. Simulator data collection at EDF – campaigns and their objectives *

Years	Number of observed simulations **	Objectives
1984 – 1988	115	– Gather Data for implementing the HRA – Observation of deviations in relation to the procedures
1989 – 1990	30	– Study of the activity of the operators
1991 – 1994	64	– Experience feedback on State-based Emergency Procedures – Update of HRA data – MERMOS development
1995 – 2003	45	– Update of HRA data – Qualitative ergonomic analyses
2003 – 2007	57	– Placing a compendium streamlined by training observations – Training of HRA experts

* Source: P. Le Bot, H. Pesme, P. MEYER, “Collecting data for MERMOS using a simulator”, contribution to the upcoming 9th Int. Conf. on Probabilistic Safety Assessment and Management (PSAM9), Hong Kong, 18-23 May, 2008.

** With the exception of the 2003-2007 observations, which took place during training sessions, all of the observed simulator sessions were dedicated sessions organized by EDF’s R&D division.

Hungary - Paks NPP and VEIKI

The initial data collection efforts at the Paks NPP were made in 1992 by making use of the experience of EPRI's so-called ORE project. The results and findings of the initial studies were used as input into the HRA for the Paks plant. These early efforts were then followed by additional data collection sessions in 1995 when a completely revised data collection taxonomy was utilized with more attention to observable effects of situational (contextual) and other factors on operators' performance. In addition to HRA objectives, the insights from the data collection sessions in 1995 were used to develop recommendations for making improvements in training, human factors, and procedures.

The latest HRA-purpose observations were carried out in 2004 to investigate changes in team work and in the effectiveness of crew performance following the implementation of new, symptom-oriented procedures at Paks in 2003. Due to this objective, more emphasis was put on procedure-related effects and problems in comparison to previous simulator studies at Paks. Using the findings from these observations the HRA for post-initiator actions was completely re-done in the Paks PSA. The approach is based on a context-dependent definition of potential lower level errors in diagnosis and in task execution followed by a fault tree representation of the relationships between these lower level errors and an HFE. Quantification is then made by solving the corresponding fault tree for an HFE.

The table below gives a short summary about the simulator studies for NPP Paks.

Table B.2. Summary of NPP Paks simulator studies in support of HRA

Year	Purpose	No. PSA Scenarios	No. of Control Room Crews Observed	Data Collection Methodology
1992	Support HRA in initial PSA for NPP Paks	5	24	Improved EPRI ORE
1995	Revise HRA and develop recommendations for plant improvement	3	24	Novel approach
2004	Update HRA/PSA after implementing new EOPs	4	24	Novel approach

Korea – KAERI

In an attempt to identify and understand the principal sources of human performance related problems, Korea Atomic Energy Research Institute (KAERI) has developed the Human Performance Database for Operator Performance and Reliability Analysis (OPERA) [20]. Using the reports of human-related reactor trips as well as simulator training sessions, KAERI has examined 101 reactor trips and videotaped 160 emergency training sessions. From these materials, KAERI analyzed error modes and cognitive functions pertaining to human related reactor trip events. In addition, through a timeline and a verbal protocol analysis, KAERI extracted various kinds of operator response time data, such as event diagnosis and task execution times, from emergency training records. More interesting data, such as the tendency of procedure compliance under emergencies were also extracted and stored in OPERA database.

Japan – JNES

In 2005, the Nuclear and Industrial Safety Agency mentioned the need to upgrade the HRA methods, i.e. the improvement of models and collection of national data. JNES launched projects aiming at the development of guidelines for collecting HRA data using plant simulators, which have been carried out from 2005 to 2007. Experiments were designed in accordance with the guidelines and conducted at BWR training centers, which have been carried out from 2006 to 2007.

Instructors participated in the experiments as subjects studied. Data collection was made for four scenarios, e.g. ATWS, LOCA at BWR4, BWR5 and ABWR type simulator. The number of simulations observed amounts to 24.

The guidelines [for collecting HRA data using plant simulators] appeared to be useful with no critical deficiency. Therefore no fundamental modifications were made to the draft guidelines.

However, there were mismatches between behaviors postulated in PSA scenarios and behaviors actually observed. In the PSA scenarios operators are expected to make recovery tasks after diagnosing equipment failures. In the simulation they make correct recovery tasks before diagnosing the equipment failures as follow:

- In ATWS, there were two cases with different operational priorities before the diagnosis; one prioritizing the insertion of control rods, another prioritizing the maintenance of the vessel water level. The subject task, i.e. the activation of SLC, was correctly implemented.

- These observations imply that actual operations are often different from those postulated in PSA.

Japan – CRIEPI

The Human Factors Research Center (HFC) in CRIEPI has programs to enhance safety and reliability of nuclear power operations. Since its establishment in 1987, HFC analyzed, in cooperation with Japanese utilities, human errors happened in Japanese NPPs with a systematic technique named HINT/J-HPES (advanced version of J-HPES) to find their latent factors and countermeasures. The data are stored Human Factors Data Base in CRIEPI to share them among the utilities. Using these data, HFC is publishing booklets and posters to share the lessons-learned and also analyzing statistically the relations between types of human errors and their latent factors. In the one of HFC’s programs, they have been studying to enhance NPPs operating team performance. In this program, a method to evaluate team work has been being developed in cooperation with operator training centers and utilities’ operating teams. This method was applied to evaluate team work of utilities’ teams facing simulated abnormal operating conditions such as LOCA, etc., and found that this method shows reasonable results. In other program, HFC is surveying factors of organisational climate, management and individual safety consciousness through questionnaire or interview to employees in NPPs. The data are analyzed to find relations of safety culture and those factors.

Norway – OECD Halden Reactor Project

Historically, experiments performed at Halden Reactor Project using simulators have tested specific human performance hypotheses or have tested support and display systems; they have not focused on collection of HRA data. However, it became clear that suitably adapted experiments (for example, the "Task Complexity Experiment", HWR-758 [21]) could also be used as sources of data for HRA/PSA if Halden signatories were to request or mandate this.

International HRA Empirical Study

The HRP plays a key role in the International HRA Empirical Study, an international evaluation study of HRA methods aimed at obtaining an empirically-based understanding of the methods' performance, strengths, and weaknesses. In this study, HRA methods are being assessed based on comparing the outcomes predicted in HRA analyses with reference data collected in the Halden's Hammlab experimental simulator facility. The results of this work are expected to provide the technical basis for selecting methods and for developing improved HRA guidance and, if necessary, improved methods.

In its pilot phase, the Empirical Study has demonstrated the value of the "rich" set of reference data obtainable from the data collected and analyzed in simulator studies, both for increasing the understanding of human performance and for evaluating HRA methods. This reference data includes not only the performance of the crews on the actions of interest and the timing of these actions, but also why the crews performed an action and the specific difficulties they had with tasks such as evaluating plant information, assessing the state of the plant, interpreting the procedures, and so on. For individual methods, this qualitative data supports a comparison that can be used to evaluate the scope of the PSFs, the guidance for their analysis, as well as the assumed relationships among the PSFs.

The contributions of the OECD Halden Reactor Project to the International HRA Empirical Study are supported by the Joint Programme of the OECD Halden Reactor Project. In addition, organisations from ten HRP member countries, representing industry, regulators, and the research community are contributing to the study.

Spain (CIEMAT, CSN, UNESA)

In the context of the Spanish membership in the HALDEN Reactor Project (HRP), CIEMAT (Centro de Investigaciones Energéticas Medioambientales y Tecnológicas, a Spanish R&D organisation) has been involved in an exploratory study on Performance Shaping Factors (PSFs) based on experimental data from the HRP "Task Complexity Experiment" [21]. At present, in Spain there is no initiative for gathering data from nuclear power plant training simulators.

Human Factors Database

In relation to data collection efforts, the "Human Factors Data Base Project" can be mentioned. Although the Spanish nuclear regulator (CSN) does not directly carry out research activities, it fosters and sponsors research projects in many different areas. The Human Factors Database project was sponsored by CSN and UNESA, the Spanish nuclear utilities association, and was performed by IBERINCO and the Spanish nuclear utilities. The goal of the project was to develop a common database for operating events occurred at the Spanish nuclear power plants with human factors issues. As a preliminary idea, the database was intended to collect all those human factors considerations that may have relevance within the event, including organisational factors as well. In this regard, initial proposals by the CSN were directed to a database for collecting current event report information based on two separate models, taking into account individual human behavior aspects (ATHEANA was suggested as a convenient human behavior model) and organisational factors (NOMAC was suggested for organisational model). Finally the database structure was based on the INPO "Human Performance Enhancement System" model classification. The project was completed in 2007; currently, the utilities are evaluating its use. The database is viewed as a starting point for future developments related to human and organisational factors, although up to now it is not intended for HRA purposes.

Czech Republic - NRI and NPP Dukovany

A simulator data collection project, which was focused on observation of VVER-440/213 NPP Dukovany control room crews, took place in time period 1998-2000. The observed exercises of control room crews were devoted to accident scenarios driven by symptom based procedures of Westinghouse type. Major part of those scenarios was closely related to accident sequences defined in NPP Dukovany PSA model. The project was supervised by US DOE with the help of technical coordinator, which was PNNL (Pacific Northwest National Laboratory). The project was done in close cooperation with VUJE Trnava Research Institute training center.

The data were collected during three series of exercises, which took place in Fall 1998, Spring 1999 and Spring 2000. For each series, the work was divided into three steps - preparation of data collection, observation of exercises and data evaluation.

The preparation activities consisted of preparation of tools for manual as well as semiautomatic data collection and detailed analysis of simulated accident scenarios. A comprehensive data collection forms were developed for the observers performing manual data collection. For semiautomatic data collection, bar code sheets were constructed. The simulated scenarios were analyzed to the highest possible level of detail in advance, along the paths, the crews were expected to go through the procedures during simulation. Every single step of these paths was evaluated regarding the following attributes: 1) step complexity 2) step length 3) structure of step (with/without warnings and/or notes) 4) executor (reactor operator/turbine operator) 5)type of activity (information processing/ control only/ manipulations) 6) risk importance of the step 7) simulator fidelity (good simulation/fidelity problems) 8) crew fatigue/concentration (first/second/third/fourth part of exercise) 9) type of procedure (emergency/abnormal status procedure). All these attributes were used later during statistical analysis of collected data, when validity of some hypotheses concerning factors influencing control room crew work was tested.

The performance of six control room crews in six simulated accident scenarios was observed during each series of exercises (altogether, almost 100 observations were carried out). Usually, two crews were observed during one day in two scenarios each. The observations included debriefing sessions. The set of scenarios covered many important PSA scenarios including steam generator tube rupture, loss of primary circuit coolant with coolant escape into as well as outside the confinement, total loss of off-site power, steam line break etc.

The data gained during observations were analyzed in qualitative as well as in quantitative manner. Emphasis was put upon statistical analysis of recorded information. Crew performance in each individual step of symptom based procedures was analyzed and marked by one of four degrees: 0 - step performed without any problems, 1 - step performed with hesitation or uncertainty, but in a correct manner finally, 2 - step performed with failure that did not significantly influence remaining part of accident scenario 3 - step performed with serious failure, simulator instructor intervention was necessary. For each crew, big number of classification points was obtained this way. This information was further evaluated to gain representative characteristics of crew performance regarding key characteristics of the steps.

Three series of data collection provided the users with big volume of information. The most important insights could be divided into three categories: 1)conclusions regarding new NPP Dukovany symptom based procedures 2)conclusions representing feedback from simulator exercises, which can be used in plant operation as well as control room crews training 3)conclusions important for NPP Dukovany PSA model.

A broad set of conclusions concerning NPP Dukovany symptom based procedures was made during evaluation of observed exercises and many of them were used by plant specialists during the time period of verification and validation of new procedures. The sophisticated methods of mathematical statistics were used for testing a group of hypotheses regarding various attributes of control room crew work. Altogether, 30 statistical hypotheses related to performance shaping factors influence were tested.

The potential for using data from simulator for direct quantification of PSA model was found low due to obvious reasons. However, after three series of exercises, there were enough data inputs to correct some probability values, which had been derived on the base of generic data during PSA project and which were found not to be in quite good coincidence with simulator observations. 12 relatively important HEP values in NPP Dukovany PSA study were modified on the base of simulator data collection.

The usefulness of newly developed methodology for simulator data collection and analysis was fully confirmed. The methodology can be used independently on the type of accident scenario, quality of simulation and concrete configuration of equipment manipulated by control room crew. Some limitations in using of the methodology are connected with close connection of it with symptom based type of procedures. However, this type of emergency procedures is used by most nuclear power plants nowadays.

Slovenia

The Slovenia nuclear regulators report that they have an HRA PSA revision under development (information from WGRisk country report). Response times for particular actions have been measured and will be incorporated a new model around Autumn 2006. These response times are to be converted into probabilities of failure on demand via Time-Reliability Correlation, for subsequent use in HRA and PSA, as appropriate.

Switzerland

The Paul Scherrer Institut, through an HRA research project funded by the Swiss Federal Nuclear Inspectorate, is contributing to the International HRA Empirical Study [16-18] (see Section of this report for a description of this study). PSI is active in the steering and assessment groups for the study, contributing to the design of the study methodology and its coordination. PSI staff also participated as an HRA analysis team in the pilot phase completed in 2007, applying PSI's CESA (Commission Error Search and Assessment) methodology. This participation continues.

United Kingdom

The principal developments in the UK currently in relation to data for probabilistic risk assessment are:

- CORE-DATA (Computerised Operator Reliability Evaluation), a computerised HRA database,
- PEAK (Proven Error Assessment Knowledge), a general-purpose development HRA programme, based on HEART, and
- NARA (Nuclear Action Reliability Assessment), a modified version of the HEART model.

All three approaches can assimilate simulator data, where these are available. So far as is known, no nuclear power plant simulator data are being collected for application to HRA/PSA at present.

CORE-DATA (Computerised Operator Reliability Evaluation)

CORE-DATA is a repository for a wide range of processed human reliability data, which includes human error probability data supported by the associated background information. The CORE-DATA database was initially developed at The University of Birmingham (Taylor-Adams and Kirwan, 1995) [22] and fully computerised as a database with the support of the UK Health and Safety Executive (Gibson and Megaw, 1999) [23]. CORE-DATA remains at The University of Birmingham and data collection to populate the database has been sponsored by a consortium of industry groups representing Nuclear, Air Traffic Control and Railway Industries. Data collection and database development has most recently been sponsored by Eurocontrol (2004-2005). The database includes data collected in the following industries: Nuclear, Offshore, Manufacturing, Railway, Chemical and Aviation. The database currently contains 413 human error probabilities and is presented in Microsoft Access.

PEAK (Proven Error Assessment Knowledge)

PEAK is an internal development project at the Health and Safety Laboratory. As a first step, this project is updating and, where appropriate, expanding the HEART Error Producing Condition (EPC) database to reflect any changes that have occurred since the method was first developed in the mid ‘80s. Currently, the project is consolidating findings from a wide range of psychological and human factors experiments conducted since the ‘80s in order to produce more accurate estimates of the strengths of EPCs and to add in new EPCs, where appropriate, for general-purpose HRA. There are several iterations planned, including revision of the Generic Task database, where appropriate, checking of the multi-factorial structure of the model and an update of the underlying theory.

Nuclear Action Reliability Assessment (NARA) (HRA Method)

In the UK, for the past decade, the principal tool used to quantify the reliabilities of human interactions in Probabilistic Safety Analyses (PSAs) has been the Human Error Assessment and Reduction Technique (HEART) [3]. Whilst this technique has served well, a review of its data sources and application in actual PSAs indicated that certain aspects of the technique would benefit from updating and refinement to better fit the Nuclear Power Plant (NPP) tasks being assessed. This led to a project to develop the technique by incorporating more recent and relevant data, and tailoring it to the needs of UK NPP PSAs. To avoid confusion with the original version of HEART, the resulting NPP specific approach to human reliability assessment has been called Nuclear Action Reliability Assessment (NARA) [24]. NARA works in the same way as HEART by first selecting an appropriate Generic Task Type (GTT) with a pre-assigned human error probability (HEP). Where the task conditions differ from those assumed for the GTT, factors are applied to modify the GTT HEP according to the Error Producing Conditions (EPCs) identified. The EPCs may be fully or partially applied according to the assessed proportion of affects (APOA).

For NARA a new list of 13 GTTs has been developed by identifying and describing the types of operator tasks modelled in a number of UK NPP PSAs. HEPs have been derived for the GTTs from recent data sources such as the Computerised Operator Reliability and Error Database (CORE-DATA) database. A new set of EPCs has also been developed by listing the EPC used in a number of UK NPP PSAs and from a review of contemporary human error identification approaches. The review of EPCs has resulted in several of the original HEART EPCs remaining unchanged, while others have been modified (e.g. increasing or decreasing their maximum effect). From this process a new set of 18 EPCs has been developed.

In addition to the above NARA has developed an approach to quantifying the effect of long time-scales on operator reliability, building on a previous research project in this area. This has been considered desirable because the operator often has a long time-scale in which to react to events. This is particularly true for UK Gas-Cooled Reactors when compared with Light Water Reactors. A prototypical approach to Error of Commission quantification has also been developed, and work is ongoing in the area of determining dependence approaches for NARA applications. With respect to consistency of usage of the technique, more guidance has been developed for use of the applied proportion of affect (APOA) process.

United States

The main HRA data-relevant work currently being undertaken in the U.S. is the Human Event Repository Analysis (HERA) [13] of Licensee Event Reports (LER). So far, the project has analysed 45 LERs which form the basis for the 700 data records and the process model is based on a concept of layering, with event description leading to error types, leading to error mechanisms and finally to cognitive linkages.

The HERA database is split into two parts, Part A, which has global information surrounding subevents and Part B, which provides an analytical worksheet for each subevent. For the plant and event overview conditions, there are two types of condition, Active Conditions and Latent Condition with the subevents coded consecutively on a timeline to show what went right, what went wrong, and at what particular point. The analysis includes consideration as to whether there might be some dependency within the subevents and the worksheet is broken into 8 sections, Diagnosis and Planning, Action, Personnel involved, Contributory Maintenance Factors, Successful Human Actions, Error Type and Comments. It is proposed to extend this analysis via doctoral sponsorship, which is currently being proposed and engineered.

No simulator data are being gathered, at present, and there are currently no plans to collect data of this sort from nuclear power plants in the near future. It should be noted, however, that the HERA database is being used to store data collected in HRA-related simulator studies at the OECD Halden Reactor Project [19].

Other recent developments related to data collection include a feasibility study on the use of empirical data and Bayesian methods in HRA (NUREG/CR-6949) [14] and NUREG/CR-6903, Vol. 2, which is the HERA Coding Manual and Quality Assurance [25].

APPENDIX C. METHODOLOGY FOR SIMULATOR STUDIES FOR HRA

The collection of information and data for HRA purposes in simulator studies requires a methodology that addresses the overall design of the study, the means for information and data collection, scenario design, and finally data analysis. In particular when the results are to be shared or exchanged, the methodology is an important element.

The importance of the methodology is two-fold. First, the methodology is an important aspect of the pedigree of the data, which affects the applicability and transferability of the data and the related insights. Second, simulator studies typically involve a substantial effort and the participation of diverse groups. Consequently, it would be important that the experience from previous studies is also shared, in order to maximize the benefits from each new study for the utility as well as for the community.

C.1 Overall study design

Some of the decisions related to the overall design of simulator studies include:

- the number of scenarios
- scenario-crew permutations, i.e. do all crews face the same scenarios? scenario variants? ordering of scenarios in multiple-scenario studies
- whether actual plant crews or composite crews participate

The objective of the studies as well as time and budget constraints will influence these decisions. Nevertheless, insights on the advantages and disadvantages of these options would be useful for organisations that wish to organize a simulator study.

C.2 Means for information and data collection

This element of the methodology addresses the collection of data and information during the simulated scenarios and in post-simulation debriefings. It includes:

- video and other technical means of recording and logging the sessions (some of these will be included in the simulator hardware/software itself)
- observation methods, checklists and forms, and training for the observers
- interview and questionnaire methods for use during exercises (pauses during simulations) as well as post-exercise debriefings.

C.3 Scenario design

This aspect of the methodology concerns the initiating events and other faults that constitute the simulator exercise. For HRA purposes, there is an interest in the human performance tendencies in more challenging scenarios, in particular in connection with the issue of "errors of commission". Simpler scenarios, e.g. design basis accident scenarios, are less likely to yield insights on potential vulnerabilities or error mechanisms. Nevertheless, they may also be useful in providing empirical support for the high level of human performance (low HEPs) credited in the PSA models for these scenarios.

In the design of scenarios, the relevance of the scenario in PSA terms as well as the plausibility of the scenario for the operating personnel need to be considered. Hardware faults and especially multiple failures need to be produced credibly in order for the study results to be relevant to actual plant practices.

C.4 Obtaining results - data analysis

Once the simulator exercises have been set up and carried out, the analysis of the simulator data, in both qualitative and quantitative terms, presents further challenges. This concerns the interpretation and processing of the timing of key events during the exercise, the actions performed, the comparison of the response to an expected or nominal response, and the examination of possible causes for differences in the response.

Sharing the experience with data analysis and suggestions for future analyses is important to ensure

- that simulator studies provides useful results for the organisation carrying out the study; and
- that the resulting conclusions, insights, and recommendations are well-founded.

C.5 Methodology – conclusion

The methodology for carrying out simulator studies for HRA purposes is an important supporting element for the exchange of HRA information from simulator studies. Fortunately, a number of studies in member countries as well as OECD Halden have been performed and may provide hints for future studies.

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