RESEARCH REPORT

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State-of-the-Art of Human Reliability Analysis for Nuclear Power Plants

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Summary

This State-of-the-Art review provides an overview of relevant guidelines, evaluations and standards concerning human reliability analysis for nuclear power plants and summarizes their key elements.

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Preface

This report was made in connection with commission work for the Radiation and Nuclear Safety Authority, Finland (STUK) regarding technical support related to the regulatory review of the Loviisa nuclear power plant human reliability analysis.

Espoo 26.11.2014

Markus Porthin

Content

1. Overview

This State-of-the-Art review provides an overview of relevant guidelines, evaluations and standards concerning human reliability analysis (HRA)for nuclear power plants (NPPs) and summarizes their key elements. Table 1 summarizes the considered HRA reference documents. An overview of recent and ongoing international activities in the field is also included.

Table 1. HRA reference documents.

Organisation	DocumentNumber	Year of issue	Document name	Key points / Main content	Availability online
International Atomic Energy Agency (IAEA)	Safety Series No. 50-P-10	1995	Human Reliability Analysis in Probabilistic Safety Assessment for Nuclear Power Plants: A Safety Practice	Practical guide describing the steps needed for incorporating HRA into PSA and the documentation that should be provided. The publication is officially no longer valid. The content is however still relevant.	http://gnssn.iaea.org/Superseded%20Safety%20Standards/Safety_Series_050-P-10_1995.pdf
United States Nuclear Regulatory Commission (NRC)	NUREG-1792	2005	Good Practices for Implementing Human Reliability Analysis (HRA)	Good practices for performing HRAs and reviewing HRAs to assess their quality. The good practices are of a generic nature and are not tied to any specific HRA methods or tools. They support the implementation of Regulatory Guide RG 1.200 for Level 1 and limited Level 2 internal event PRAs with the reactor at full power. The report is not a standard and does not provide de facto requirements; rather, is intended for use as a reference guide.	http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1792/

United States Nuclear Regulatory Commission (NRC)	NUREG-1842	2006	Evaluation of Human Reliability Analysis Methods Against Good Practices	An evaluation of the various HRA methods that are commonly used in regulatory applications in the United States, with a particular focus on the extent to which they provide guidance to satisfy the good practices reported in NUREG-1792. The HRA methods are also evaluated against the Probabilistic Risk Assessment (PRA) Standard (RA-S-2002) promulgated by the American Society of Mechanical Engineers (ASME). Includes observations regarding the respective strengths and limitations of the HRA methods, as well as summaries of the scope, underlying knowledge base, and sources of quantification data associated with each method.	http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1842/
Health and Safety Ececutive (HSE)	RR679	2009	Review of human reliability assessment methods	An assessment of quantitative HRA methods focusing on their capability, strengths and weaknesses. The report forms a view on the ‘acceptability’ of the various tools for use in risk assessments from HSE’s point of view.	http://www.hse.gov.uk/research/rrhtm/rr679.htm
The Institute of Electrical and Electronics Engineers (IEEE)	IEEE Std 1082-1997(R2010)	1997, reaffirmed 2010	IEEE Guide for Incorporating Human Action Reliability Analysis for Nuclear Power Generating Stations	A structured framework for the incorporation of human/system interactions into probabilistic risk assessments for nuclear power plants.	http://ieeexplore.ieee.org/servlet/opac?punumber=5186
Paul Scherrer Institute (PSI)	HSK-AN-3584	2000	Guidelines for the Regulatory Review of Human Reliability Analysis in PSA	HRA quality is addressed in the guidelines in terms of 97 indicators. Two HRA stages are distinguished: • selection of the human errors to be modelled • quantification of their impact on the core damage frequency.	Not available online A short summary is available at http://inis.iaea.org/search/search.aspx

				Review findings are grouped under two headings: • transparency • adequacy The review is structured in two phases: 1. The Quick Review, which clarifies whether the HRA has a fundamental deficiency and, furthermore, if it points to information needs and areas of emphasis for the detailed review, and 2. The Detailed Review, which results in well-grounded findings, based on extended examinations and close-plant contacts.	?orig_q=RN:31032980
National Aeronautics and Space Administration (NASA)	NASA/OSMA Technical Report	2006	Human Reliability Analysis Methods: Selection Guidance for NASA	The report is intended to provide the NASA risk analyst with a familiarization of the HRA process, a list of recommended methods, and rationale used as the basis for the selection of these methods for use in risk evaluations of NASA's programs.	http://www.hq.nasa.gov/office/codeq/rm/reference.htm

Several of the HRA reference documents and recent or ongoing international activities evaluate specific HRA methods. Table 2 describes which methods are considered in which document or study.

Table 2. Overview of HRA methods considered in HRA reference documents and studies.

Acronym	Full name	NUREG-1842	HSE RR679	NASA	Int. HRA empirical study	OECD CSNI WG Risk / WGHOF
ASEP	Accident Sequence Evaluation Programme	X	X	X	X	X
APJ	Absolute Probability Judgement		X			

ATHEANA	A Technique for Human Error Analysis	X	X	X	X	X
CAHR	Connectionism Assessment of Human Reliability		X	X		
CBDT	EPRI Caused Based Decision Tree	X		X	X	X
CESA	Commission Errors Search and Assessment		X	X		
CESA-Q	Commission Errors Search and Assessment – Quantification				X	
CODA	Conclusions from occurrences by descriptions of actions		X			
CREAM	Cognitive Reliability and Error Analysis Method		X	X	X	X
DT	Decision Trees				X	
Enhanced Bayesian THERP	Enhanced Bayesian Technique for Human Error Rate Prediction				X	X
EPRI	Electric Power Research Institute HRA Calculator®	X				
FLIM	Failure Likelihood Index Methodology	X				X
HCR/ORE	Human Cognitive Reliability / Operator Reliability Experiments	X				X
HEART	Human Error Assessment and Reduction Technique		X	X	X	
HF PFMEA	Human Factors Process Failure Modes & Effects Analysis			X		
HRMS	Human Reliability Management System		X			

HURECA	Human Reliability Evaluator for Control Room Actions					X
INTENT	Not an acronym		X			
JHEDI	Justified Human Error Data Information		X			
K-HRA	Korean Human Reliability Analysis				X	
MERMOS	Method d'Evaluation de la Realisation des Missions Operateur pour la Surete (Assessment method for the performance of safety operation.)		X		X	X
NARA	Nuclear Action Reliability Assessment		X	X		X
PC	Paired comparisons		X			
SHARP1	A Revised Systematic Human Action Reliability Procedure	X				
SLIM	Success likelihood index methodology			X		
SLIM-MAUD	Success likelihood index methodology, Multi-Attribute Utility Decomposition	X	X			
SPAR-H	Standardized Plant Analysis Risk Human Reliability Assessment	X	X	X	X	X
THERP	Technique for Human Error Rate Prediction	X	X	X	X	X
TRC	Time Reliability Correlation			X		
UMH	University of Maryland Hybrid			X		

2. HRA reference documents

2.1 IAEA Safety Series No. 50-P-10, Human Reliability Analysis in Probabilistic Safety Assessment for Nuclear Power Plants: A Safety Practice

This document [1] presents a practical approach for incorporating HRA into probabilistic safety assessment (PSA). It describes the steps needed and the documentation that should be provided both to support the PSA itself and to ensure effective communication of important information arising from the studies. It also describes a framework for analysing those human actions which could affect safety and for relating such human influences to specific parts of a PSA.

The objectives of the publication are:

- to present a practical and standardized approach and terminology for HRA in PSA;
- to describe a framework in which different types of human actions are related to specific parts of a PSA;
- to describe acceptable methods and data sources for analysing the human
- actions; and
- to show how the HRA is integrated into the rest of the PSA.

The publication is officially no longer valid. The content is however still relevant.

2.2 NUREG-1792, Good Practices for Implementing Human Reliability Analysis (HRA), U.S. Nuclear Regulatory Commission

This report [2] documents good practices for performing HRAs and assessing the quality of those analyses. The good practices are of a generic nature and are not tied to any specific HRA methods or tools. They support the implementation of Regulatory Guide RG 1.200 for Level 1 and limited Level 2 internal event PRAs with the reactor at full power. The report is not a standard and does not provide de facto requirements; rather, is intended for use as a reference guide.

The HRA good practices are written in the context of a risk assessment for commercial NPP operations occurring nominally at full power. The guidance is specifically for HRAs for reactor, full-power, and internal events applications, although most of the guidance should be useful for other applications (e.g., external events and other operating modes).

The report is not written with the expectation that all good practices should always be met. That is, the decisions regarding which good practices are applicable — and the extent to which those practices should be met — depends on the nature of the given regulatory application. Therefore, it is important to understand that certain practices may not be applicable for a given analysis, or their applicability may be of limited scope.

The good practices are summarized in Table 3.

Table 3. Summary of good practices for implementing HRA [2]

Analysis Activity	Good Practice
HRA team formation and techniques for a realistic analysis	GP 1: Perform a Multi-Disciplinary, Integrated Analysis GP 2: Perform Field Observations and Discussions
Pre-Initiators: Identifying human actions that could leave equipment unavailable	GP 1: Review Pre-Initiator Procedures, Actions and Equipment GP 2: Do Not Ignore Pre-Initiators GP 3: Examine Other Operational Modes and Routine Actions Affecting Structures (if applicable) GP 4: Identify Actions Affecting Redundant and Multiple Diverse Equipment.
Pre-Initiators: Screening human actions that do not need to be modeled	GP 1: Screen Pre-Initiators with Acceptable Restoration Mechanisms or Aids. GP 2: Do Not Screen Actions Affecting Redundant and Multiple Diverse Equipment. GP 3: Reevaluate the Screening Process for Special Applications.
Pre-Initiators: Modeling specific HFEs corresponding to the unscreened human actions	GP 1: Include HFEs for Unscreened Human Actions in the PRA Model.
Pre-Initiators: Quantifying the corresponding human error probabilities (HEPs) for the specific HFEs	GP 1: Use Screening Values During the Initial Quantification of the HFEs. GP 2: Perform Detailed Assessments of Significant HFEs. GP 3: Revisit the Use of Screening Values vs. Detailed Assessments for Special Applications. GP 4: Account for Plant- and Activity-Specific PSFs in the Detailed Assessments. GP 5: Apply Plant-Specific Recovery Factors. GP 6: Account for Dependencies Among the HEPs in an Accident Sequence. GP 7: Assess the Uncertainty in HEPs. GP 8: Evaluate the Reasonableness of the HEPs Obtained Using Detailed Assessments.
Post-Initiators: Identifying post-initiator human actions	GP 1: Review Post-Initiator Related Procedures and Training Materials. GP 2: Review Functions and Associated Systems and

Note: The three GPs associated with this activity are to be performed in an iterative manner and a stringent order is not implied.	Equipment to be Modeled in the PRA. GP 3: Look for Certain Expected Types of Actions.
Post-Initiators: Modeling specific HFEs corresponding to the human actions	GP 1: Include HFEs for Needed Human Actions in the PRA Model. GP 2: Define the HFEs Such that they are Plant- and Accident Sequence-Specific. GP 3: Perform Talk-Throughs, W alkdowns, Field Observations, and Sim ulator Exercises (as necessary) to Support the Modeling of Specific HFEs.
Post-Initiators: Quantifying the corresponding HEPs for the specific HFEs	GP 1: Address Both Diagnosis and Response Execution Failures. GP 2: Use Screening Values During the Initial Quantification of the Post-Initiator HFEs. GP 3: Perform Detailed Assessm ents of Significant Post-Initiator HFEs. GP 4: Revisit the Use of Post-Initiator Screening Values vs. Detailed Assessments for Special Applications. GP 5: Account for Plant- and Activity-Specific PSFs in the Detailed Assessments of Post-Initiator HEPs. GP 6: Account for Dependencies Among Post-Initiator HFEs. GP 7: Assess the Uncertainty in HEPs. GP 8: Evaluate the Reasonableness of the HEPs Obtained Using Detailed Assessments.
Post-Initiators: Adding recovery actions to the PRA	GP 1: Define Appropriate Recovery Actions. GP 2: Account for Dependencies. GP 3: Quantify the Probability of Failing to Perform the Recovery(ies).
Errors of Commission (EOCs)	GP 1: Address EOCs in Future HRAs/PRAs (Recommendation). GP 2: As a Minimum, Search for Conditions that May Make EOCs More Likely.
HRA Documentation	GP 1: Document the HRA.

2.3 NUREG-1842, Evaluation of Human Reliability Analysis Methods Against Good Practices, U.S. Nuclear Regulatory Commission

Various HRA methods that are commonly used in regulatory applications in the United States are evaluated in the report [3]. A particular focus is put on the extent to which the methods provide guidance to satisfy the good practices reported in NUREG-1792. The evaluated methods are listed in Table 4.

Table 4. HRA methods evaluated in NUREG-1842

Acronym	Full name
ASEP	Accident Sequence Evaluation Programme
ATHEANA	A Technique for Human Error Analysis
CBDT	EPRI Caused Based Decision Tree
EPRI	Electric Power Research Institute HRA Calculator®
FLIM	Failure Likelihood Index Methodology
HCR/ORE	Human Cognitive Reliability / Operator Reliability Experiments
SHARP1	A Revised Systematic Human Action Reliability Procedure
SLIM/MAUD	Success likelihood index methodology / Multi-Attribute Utility Decomposition
SPAR-H	Standardized Plant Analysis Risk Human Reliability Assessment
THERP	Technique for Human Error Rate Prediction

A general description of each method is given, followed by a summary of Method-Against-Good-Practices (NUREG-1792) Analysis Activities and helpful hints for examining the technical adequacy of an HRA using the evaluated method.

Each evaluated HRA method is also summarized with regard to the following key characteristics:

- Scope
- Underlying model
- Underlying data
- Quantification approach
- Strengths
- Limitations

2.4 Review of human reliability assessment methods. Health and Safety Ececutive (HSE), Research Report RR679

The report [4] reviews the literature to identify the range of qualitative and quantitative HRA techniques available and carries out an assessment of their strengths and weaknesses.

A total of 72 potential human reliability related tools and acronyms were identified. Of these, 37 were excluded from any further investigation and 35 were identified as potentially relevant to HSE major hazard directorates and were investigated fully. Of the 35 potentially relevant HRA tools, 17 were considered to be of potential use to major hazards directorates (Table 5). The tools are classified as first, second and third generation as well as expert judgment methods.

Table 5 A list of the 17 tools considered to be of potential use to HSE major [4]

		Acronym	Full name	Comment	Domain
Publicly available	1st generation	THERP	Technique for Human Error Rate Prediction	A comprehensive HRA approach developed for the USNRC	Nuclear with wider application
		ASEP	Accident Sequence Evaluation Programme	A shortened version of THERP developed for the USNRC	Nuclear
		HEART	Human Error Assessment and Reduction Technique	Relatively quick to apply and understood by engineers and human factors specialists. The method is available via published research papers. (A manual is available via British Energy).	Generic
		SPAR-H	Standardized Plant Analysis Risk Human Reliability Assessment	Useful approach for situations where a detailed assessment is not necessary. Developed for the USNRC. Based on HEART.	Nuclear with wider application
	2nd generation	ATHEANA	A Technique for Human Error Analysis	Resource intensive and would benefit from further development. Developed by the USNRC	Nuclear with wider application
		CREAM	Cognitive Reliability and Error Analysis Method	Requires further development. Available in a number of published references.	Nuclear with wider application
	Expert judgement	APJ	Absolute Probability Judgement	Requires tight controls to minimise bias, otherwise validity may be questionable. Viewed by some as more valid that PC and SLIM.	Generic
		PC	Paired comparisons	Requires tight controls to minimise bias, otherwise validity may be questionable	Generic
		SLIM-MAUD	Success likelihood index methodology, multi-attribute utility decomposition	Requires tight controls to minimise bias of the SLIM element, otherwise validity can be questionable.	Nuclear with wider application

				The SLIM element is publicly available.	
Not publicly available	1st generation	HRMS	Human Reliability Management System	Comprehensive computerised tool. A proprietary method.	Nuclear
		JHEDI	Justified Human Error Data Information	Faster screening technique than HRMS, its parent tool. A proprietary method.	Nuclear
		INTENT	Not an acronym	Narrow focus on errors of intention. Little evidence of use but potentially useful. Available by contacting the authors.	Nuclear
	2nd generation	CAHR	Connectionism Assessment of Human Reliability	A database method that is potentially useful. Available by contacting the authors (CAHR website).	Generic
		CESA	Commission Errors Search and Assessment	Potentially useful. Available by contacting the authors.	Nuclear
		CODA	Conclusions from occurrences by descriptions of actions	Requires further development and CAHR or CESA may be more useful. Available by contacting the authors.	Nuclear
		MERMOS	Method d'Evaluation de la Realisation des Missions Operateur pour la Surete (Assessment method for the performance of safety operation.)	Developed and used by EdF, its development is ongoing. A proprietary tool.	Nuclear
	3rd gener.	NARA	Nuclear Action Reliability Assessment	A nuclear specific version of HEART (different author to the original). A proprietary tool.	Nuclear

For each of these 17 methods, a brief summary was prepared that includes:

- What they claim to offer and how they work (their scope, approach and information on the underlying models of the methods);
- The advantages and disadvantages of the method based on objective information available in the research literature;
- A comment on their potential application and major hazard sectors for which they would be suitable (if appropriate);
- A comment on their validity; and
- A note of the resources required for their use.

2.5 IEEE Std 1082™-1997(R2010), IEEE Guide for Incorporating Human Action Reliability Analysis for Nuclear Power Generating Stations

This guide [5] provides a structured framework and outlines the steps necessary for the incorporation of human/system interactions into probabilistic risk assessments (PRAs). It is not its intent to discuss the details of HRA methods, since this technology is evolving and cannot be addressed in the needed depth in this guide. Since human error has been found to be an important contributor to risk, this guide underscores the systematic integration of the HRA at the earliest stages and throughout the PRA.

The purpose of this guide is to enhance the analysis of human/system interactions in PRAs, to help ensure reproducible conclusions, and to standardize the documentation of such assessments. To do this, a specific human reliability analysis (HRA) framework is developed from standard practices to serve as a benchmark to assess alternative ways of incorporating HRA into PRA (Figure 1).

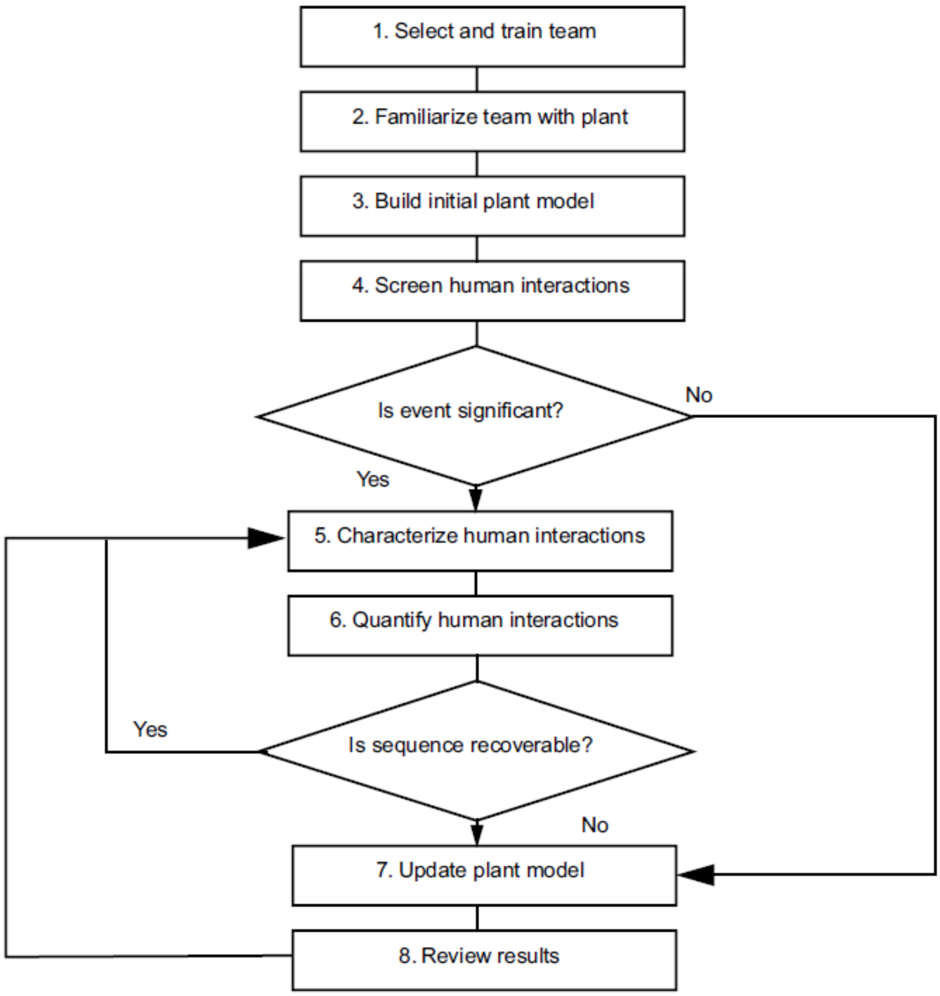

Figure 1. The HRA process [5].

The guide empasizes that the HRA should be incorporated within the PRA in a stepwise manner. A generic HRA process is presented that forms a basis for auditable documentation of the HRA. Each step is described in detail in the guide, including a statement of purpose, a description of the step, and a statement of output.

2.6 Guidelines for the Regulatory Review of Human Reliability Analysis in PSA, Paul Scherrer Institute, HSK-AN-3584

PSI was commissioned to develop Guidelines for the Regulatory Review of the HRA within PSAs for NPPs [6]. In the Guidelines, HRA quality is addressed in terms of 97 indicators. Each indicator is formulated as a question, described as a specific feature of the analysis, and then explained in detail. Two analysis stages are distinguished: the selection of the human errors to be modelled, and their quantification to determine their impact on the core damage frequency. Review findings are grouped under two headings: transparency and adequacy. An analysis is 'transparent' if an externally qualified person is able to reproduce the analysis results, and 'adequate' if such results reflect the plant-specific conditions related to safety. To allocate resources efficiently, the review is structured in two phases: (1) The Quick Review, which clarifies whether the HRA has a fundamental deficiency and, furthermore, if it points to information needs and areas of emphasis for the detailed review, and (2) The Detailed Review, which results in well-grounded findings, based on extended examinations and close-plant contacts.

The proposed review process is summarized in Figure 2.

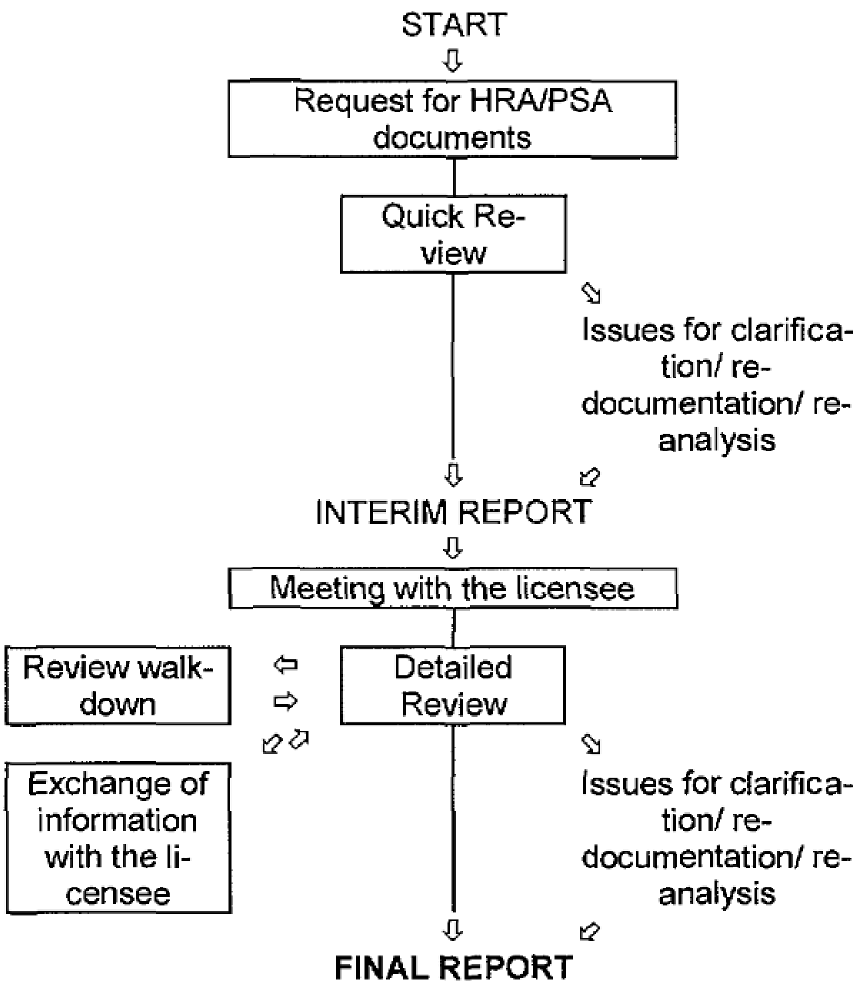

Figure 2. Overall HRA review flow chart [7].

2.7 Human Reliability Analysis Methods: Selection Guidance for NASA

The purpose of this report [8] is to give an overview of the HRA process and describe what HRA methods can be used for NASA projects.

Section 1 provides a general overview of the HRA process, describes NASA's unique performance shaping factors, provides a set of recommended quantitative HRA methods for NASA use, and offers guidelines for selecting the appropriate method. The second section provides a description of the NASA HRA methods study, the criteria used to select methods for the evaluation, and the criteria used to compare the methods for the final selection. Section 3 provides a detailed look at the results of the study for each method evaluated. The appendices provide additional details on NASA requirements and performance shaping factors.

This report is not intended to instruct a novice on how to perform HRA. Rather, it is intended to provide the risk analyst with a familiarization of the HRA process, a list of recommended methods, and rationale used as the basis for the selection of these methods. The HRA methods evaluated in the report are listed in Table 6.

Table 6. HRA methods evaluated in the report.

Acronym	Full name
ASEP	Accident Sequence Evaluation Programme
ATHEANA	A Technique for Human Error Analysis
CAHR	Connectionism Assessment of Human Reliability
CBDT	EPRI Caused Based Decision Tree
CESA	Commission Errors Search and Assessment
CREAM	Cognitive Reliability and Error Analysis Method
HEART	Human Error Assessment and Reduction Technique
HF PFMEA	Human Factors Process Failure Modes & Effects Analysis
NARA	Nuclear Action Reliability Assessment
SLIM	Success likelihood index methodology
SPAR-H	Simplified Plant Analysis Risk Human Reliability Assessment
THERP	Technique for Human Error Rate Prediction
TRC	Time Reliability Correlation
UMH	University of Maryland Hybrid

The methods were evaluated with regard to the following attributes:

1. Developmental Context
2. Screening

3. Task Decomposition
4. PSF List and Causal Model
5. Coverage
6. HEP Calculation Procedure
7. Error-Specific HEPs
8. Task Dependencies and Recovery
9. HEP Uncertainty Bounds
10. Level of Knowledge Required
11. Validation
12. Reproducibility
13. Sensitivity
14. Experience Base
15. Resource Requirements
16. Cost and Availability
17. Suitability for NASA Applications

Based on the evaluation, four HRA methods were recommended for NASA use. NASA constrained the method selection to those method(s) that are immediately available for use and are applicable for analysis of new aerospace designs. The recommended methods are:

- THERP,
- CREAM,
- NARA,
- SPAR-H.

3. Recent and ongoing international activities in HRA

3.1 The international HRA empirical study

The International HRA Empirical Study (2007-2013) is a three-phase multinational, multiteam effort supported by the Organization for Economic Cooperation and Development (OECD) Halden Reactor Project, the Swiss Federal Nuclear Safety Inspectorate, the U.S. Electric Power Research Institute, and the U.S. Nuclear Regulatory Commission (NRC) [9, 10, 11, 12].

The objective of this study was to develop an empirically based understanding of the performance, strengths, and weaknesses of different HRA methods used to model human response to accident sequences in PRAs. The empirical basis was developed through experiments performed at the Halden Reactor Project HAMMLAB (HAlden huMan-Machine LABoratory) research simulator, with real crews responding to accident situations similar to those modeled in PRAs. The scope of the study was limited to HRA methods thought appropriate for use in PRAs evaluating internal events during full power operations of current light water reactors. The study consisted of performing HRAs for predefined human actions, with different HRA teams using different methods. Nuclear power plant crews performed these human actions at the Halden simulator, Halden experimentalists collected and interpreted the data to fit HRA data needs, and an independent group of experts compared the results of each HRA method/team to the Halden crew performance data. The HRA methods used by the teams were:

- ASEP
- ASEP/THERP
- ATHEANA
- CBDT + THERP
- CESA_Q

- CREAM
- Decision Trees + ASEP
- Enhanced Bayesian THERP
- HEART
- K-HRA
- MERMOS
- PANAME
- SPAR-H

The Pilot Phase consisted of developing, testing, and revising the study's methodology and design. Phase 2 consisted of the comparison of HRA predictions for nine steam generator tube rupture human actions. Phase 3 consisted of the comparison of four loss-of-feedwater human actions. The overall findings of the Study are documented in a separate report.

The results of the study include assessments of the HRA methods, conclusions about HRA and the HRA methods, conclusions on the use of empirical HRA data and benchmarking as well as overall conclusions.

The results provide a technical basis for improving individual methods, improving existing guidance documents for performing and reviewing HRAs (e.g., NUREG-1792, HRA Good Practices), and developing additional guidance and training materials for implementing individual methods.

As a follow-up, a new study is being conducted by many of the same participants as in the International study [13]. This study, referred to as the US HRA Empirical Study, uses operating crew data collected on a US nuclear power plant (NPP) simulator and is testing the consistency of the qualitative and quantitative HRA predictions among HRA teams using a given method. In other words, one of the aims of the US HRA Empirical Study is to examine the “user effect”. In addition, the US study addresses other concerns with methodological aspects of the present study.

The results of the international HRA empirical study are documented in Halden Reactor Project and U.S. Nuclear Regulatory Commission reports. The NRC reports are publicly available at http://www.nrc.gov/reading-rm/doc-collections/nuregs/agreement/ia0216/.

3.2 OECD CSNI WGRISK / WGHOF task on Establishing Desirable Attributes of HRA Methods for Nuclear Risk Assessment

OECD CSNI WGRISK / WGHOF (Committee on the Safety of Nuclear Installations, Working Groups on Risk Assessment / Human and Organisational Factors) is undertaking a task on Establishing Desirable Attributes of HRA Methods for Nuclear Risk Assessment. The activity started in 2012 and is expected to be finalized during 2014 [14, 15].

The objectives of the activity are to:

- Derive a set of attributes against which HRA methods can be evaluated
- Conduct an evaluation of HRA methods used in OECD member countries for nuclear risk assessment
- Provide a basis from which HRA users can select appropriate HRA methods for different HRA applications

Attributes for the HRA method evaluation were derived by a Task Group comprising international experts in the areas of Human Factors, HRA and PSA, including both regulators, licensees and technical support organisations. The attributes were derived based on reviews of regulatory requirements and guidance, current HRA practice and extant HRA method evaluations. A set of 20 attributes grouped into 5 broad categories was derived:

- Construct Validity (4 attributes)
- Content Validity (7 attributes)
- Empirical Validity (1 attribute)
- Reliability (2 attributes)
- Usability (6 attributes)

Each attribute was rated for importance using a four-level scale (Essential - Highly Desirable - Desirable – Indifferent). For each attribute, a 3 or 2 point evaluation scale was developed. A number of attributes were divided into sub-scales, resulting in 28 scales in total.

The evaluated HRA methods were:

- THERP Family – THERP + ASEP,
- Enhanced Bayesian THERP
- ATHEANA
- MERMOS
- NARA
- SPAR-H
- HCR/ORE & CBDT
- CREAM
- FLIM
- HURECA

In the method evaluation, each HRA method was first reviewed by its developer to identify evidence in relation to the attributes. Each HRA method was then reviewed by two members of the Task Group rating it qualitatively against each attribute. Commentary on the adequacy with which the method meets the attribute was also given. The reviews were then discussed by the Task Group attempting to achieve consensus evaluations. Finally, the accuracy was checked by the HRA method developers.

The main findings of the evaluation were:

- HRA methods were evaluated positively in relation to construct validity (good theoretical or data basis for most methods)
- Areas of content validity, where methods generally were evaluated as weak were
  - Deviations and progressions in accident sequences
  - Treatment of organisational issues
- There is little statistical evidence to support empirical validity and reliability of the methods
- The methods generally do not provide guidance on dealing with uncertainties in qualitative modelling

The Task Group could not reach a consensus on what constitutes adequate treatment of diagnostic error and whether or not safety culture can be considered by HRA methods.

3.3 EXAM-HRA

EXAM-HRA is a co-operation project where HRA practices are compared among German, Swedish, Finnish, Swiss and German NPPs [16]. The 2012 – 2014 project is partly funded by NKS (Nordic Nuclear Safety Research), the paticipating utilities, the Swedish regulator SSM and SAFIR (The Finnish Research Programme on Nuclear Power Plant Safety).

The overall objective of the project is to provide guidance for a state-of-the-art HRA for purposes of PSA and provide means to improve plant features based on HRA and PSA results.

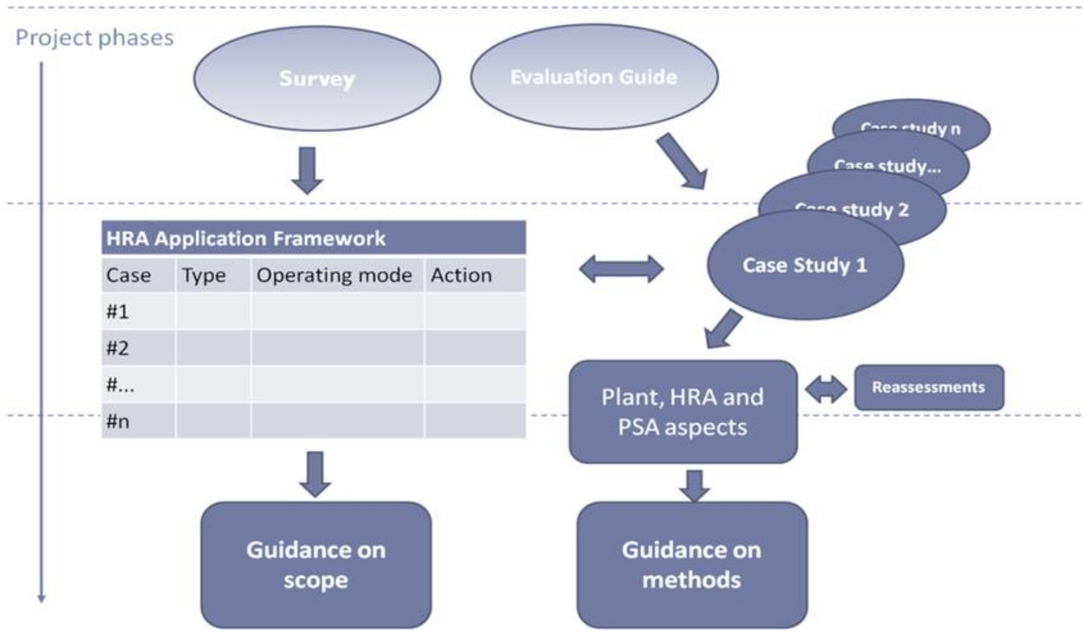

Figure 3. Overview of the EXAM-HRA project [16].

An overview of the project is given in Figure 3. The human failure basic events taken into account in the HRA of each utility have been surveyed. Furthermore, a set of case studies are conducted comparing how specific HRA aspects have been treated in the different analyses. Based on these insights two guidance documents are developed:

- Guidance on actions and scenarios to be included in HRA assessments
- Guidance on selection of HRA methods

3.4 Human-automation collaboration in incident and accident situations (HACAS)

The project Human-automation collaboration in incident and accident situations (HACAS) [16] is part of the 2011 – 2014 funding period of SAFIR (The Finnish Research Programme on Nuclear Power Plant Safety).

The project focuses on studying how digital automation (I&C) and control room (CR) upgrades affect resilient performance of CR personnel, how Human Factors Engineering (HFE) activities should be organized in order to support plant safety and productivity, and how humans and automation systems collaborate to accomplish safety and production goals of NPPs. The aim is also to develop expertise on the accomplishment of different HFE activities, strengthen delivery of expertise in Finland in the field of activity-centred design of NPP CR systems and further promote international collaboration with research and expert organizations and institutions.

The main tasks of the project are:

1. Proceduralized activity in the new accident management
2. Development of an integrated approach to HFE
3. Automation awareness and automation competence development

One of the tasks within main task 2 focuses on consideration of the interrelationships between HRA and CR system validation. The aim is to investigate how HRA should be considered in the design and implementation of CR system validation activities, and how CR validation results should be considered in HRA, specifically in the modelling and quantification of errors that occur after an initiating event (i.e., type C HRA).

The project will help designers, representatives of NPPs and authorities to better take into consideration Human Factors issues in their work. The results provide information of prospects, limitations and risks of new technologies and procedures, as well as guidelines concerning their development and training. The results will also help in developing guidance for more unified and comprehensive HFE processes and for the management and control of HFE activities in both modernization and new build projects, and for the design and evaluation of safety-critical I&C systems, procedures and HSIs.

The specific results of the project are:

- Support for the development of safe operational practices for accident management based on resilient use of EOPs and HSIs.
- Direct evidence of functionality, usability and safety of hybrid CRs especially in incident and accident situations.
- Procedures and practices for the design and evaluation of CR systems from the HFE perspective.
- Information about the prospects and challenges in the acquisition of competence based on digital automation, CR systems and new procedures. The results can be used in the development of methods and practices for operator and maintenance personnel training.

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