Unclassified **NEA/CSNI/R(97)24**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

OLIS : 23-Feb-1998
Dist. : 06-Mar-1998

English text only

NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

RESEARCH STRATEGIES FOR HUMAN PERFORMANCE

62246

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Unclassified
English text only

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article I of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral. non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

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 all OECD Member countries except New Zealant and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

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

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The Committee on the Safety of Nuclear Installations (CSNI) of the OECD Nuclear Energy Agency (NEA) is an international committee made up of senior scientists and engineers. It was set up in 1973 to develop, and co-ordinate the activities of the Nuclear Energy Agency 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 among the OECD Member countries.

The CSNI constitutes a forum for the exchange of technical information and for collaboration between organisations which can contribute, from their respective backgrounds in research, development, engineering or regulation, to these activities and to the definition of the programme of work. It also reviews the state of knowledge on selected topics on nuclear safety technology and safety assessment, including operating experience. It initiates and conducts programmes identified by these reviews and assessments in order to overcome discrepancies, develop improvements and reach international consensus on technical issues of common interest. It promotes the co-ordination of work in different Member countries including the establishment of co-operative research projects and assists in the feedback of the results to participating organisations. Full use is also made of traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences and specialist meetings.

The greater part of the CSNI's current programme is concerned with the technology of water reactors. The principal areas covered are operating experience and the human factor, reactor coolant system behaviour, various aspects of reactor component integrity, the phenomenology of radioactive releases in reactor accidents and their confinement, containment performance, risk assessment, and severe accidents. The Committee also studies the safety of the nuclear fuel cycle, conducts periodic surveys of the reactor safety research programmes and operates an international mechanism for exchanging reports on safety related nuclear power plant accidents.

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

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ABSTRACT

Knoweldge about factors that influence Human Performance is essential for the safety of nuclear power plant operation. Through a number of tasks, workshops and projects, experience is shared among OECD countries.

The present report summarises the short and long-term proposals for CSNI activities regarding Human Performance and also gives priorities for international cooperation in the area of Human Performance based on the experience in Member Countries.

1. INTRODUCTION

At its December 1996 meeting, the CSNI endorsed the SESAR/CAF report *on "Nuclear Safety Research in OECD Countries: Capabilities and Facilities*" and requested that the Principal Working Groups (PWGs) review existing co-operative programmes and develop specifications for programmes which address the identified needs.

Following discussions between the chairmen of these PWGs and the NEA Secretariat, it was concluded that, for this technical area, the development of programme specifications must be preceded by the development of a strategic document that further elaborates the conclusions of the SESAR/CAF report and set out the general orientation of the research over the medium and long term. Accordingly, a group of senior experts met in August 1997 to discuss possible strategies in the area of Human Performance. The objectives of this meeting were:

- To exchange information on existing plans and strategies by different Member countries;
- To determine relevant issues and realistic medium/long-term targets and expectations for their resolution, and
- To determine, in general sense, possible research programmes, their priority and their likelihood for success.

This document is the result of this meeting. Its objective is to present to the CSNI proposals for future work on Human Performance research. The proposals are built upon the work performed to date by PWG1 and PWG5. Carrying out these proposals will continue to require close coordination on joint activities between these two PWGs.

Reinforced systematic networking activities are needed particularly in management and organisational performance research to initiate and manage comparison and benchmarking activities. Synchronising the availability of funding is a specific problem in many cases. Since most human factors issues have a common generic basis, joint projects and sharing of facilities and experts with other industries are of high value.

2. STRATEGY OF RESEARCH AND PROPOSALS FOR FURTHER WORK

Member countries continue to have a high interest in understanding human behaviours not only as individuals but also as groups, in co-operation of groups and in the decision-making process. The characteristics of human behaviour are more or less common. These behaviours highly depend on the context of the situation or the context of their activities. The shaping factors which influence their performances have to be well understood. Particular interest can be found for human behaviour during the gathering information or assessment process activities, in risky situations or activities, in stressful conditions or in plant disturbance situations. Understanding this could be helpful to enable better mastery of error mechanisms in such situations and to improve or develop cognitive models for PSA. The data collection for such area should come from event analysis, observation of specific works, interview with operators, following methodologies which have to be defined. The programme to complete the research in these areas could be discussed with experts in workshops or specialists' meetings. Examples of research included in existing plans of member countries are summarised in Annex 1. Additionally, researches carried out also in other areas like Halden or other joint undertakings internationally. The research areas have been grouped in the categories as can be seen in the table below:

Category A: The research areas of data collection for support of cognitive modelling and understanding of Human Performance

Category B: Research in the areas of optimum design of control rooms

Category C: This category groups various research areas for evaluation of human performance safety issues

A. Basic Knowledge and Data	**B. Design**	**C. Evaluation**
1. Cognitive models	1. Control room design and man-machine interactions	1. Organisational practices
2. Use of simulators	2. Operator Aids	2. Shutdown
		3. Decommissioning
		4. Methods for evaluation of operating experience
		5. HRA Validation
		6. Safety culture
		7. Procedures*

* Added after the expert group meeting.

Parts of the activities could fall into some of the other categories. The intention is to give some headings. The paragraphs below summarise the discussions on a number of issues developed by the expert group and proposals for coordinated joint efforts between PWG1 and PWG5.

A.1 Cognitive models and Errors of Commission

Efforts should continue to collect data to support studies of cognitive models, errors of commission, and application of selected portions of these models for treatment of innovative recovery actions. The present task under PWG1 on the International Common Cause Failure Data Exchange ***(ICDE)*** might serve as a model for the collection and dissemination of data associated with cognitive errors. As part of development of this effort, the need for and use of additional simulator experiments should be considered. Cognitive models under development in member countries should be tested against this database. This effort once developed should establish models suitable for use in PSAs. A Task group should develop format, procedures and initiate actions in order to make progress.

A.2 Use of Simulators

Simulators provide a unique capability for training operators to respond to infrequent or rare events. This is particularly true when training involves the response to accidents. If simulators of high fidelity are available, they can provide data, both quantitative and qualitative, which can be used to develop models useful in developing models of Human Performance, both individual and as a group, for use in PSA models, particularly those involving actions taken outside normal operating procedures. Model development is also needed. This will, of necessity, include some definition of the degree of fidelity needed for the simulator in its specific application.

B.1 Control Room Design and Man-Machine Interactions

Member countries are either considering new control room designs or are evaluating hybrid control rooms as digital equipment replace analogue equipment which has aged. Thus, there is a need to develop methods to assess, compare and optimise the man-machine interface associated with new or hybrid control rooms and give careful consideration of long term effects. Further, criteria is needed for evaluating the adequacy of the safety design of new or hybrid control rooms. Such effort should remain cognisant of the significant work in this regard being conducted at the OECD Halden Reactor Project and other simulator experiments. A workshop should be organised to generate contribution to a state-of-the-art report including the aspects of balancing automation and human interaction.

B.2 Operator Aids

The use of computer based operator aids is rapidly increasing and is an evolving area in many Member countries. The PWG1/ETF should perform a brief survey from the Member countries and the Halden and other projects on evaluation of the effects on operators with the developed aids.

C.1 Organisational Practices

Several programmes exploring the influence of organisational practices have recently been initiated in Member countries. While these research programmes are still in their formative phases, there is a need for a small workshop with the objective to producing a state-of-the-art report. The synergism leading researchers from Member countries gathering together may greatly increase the likelihood of success of programmes newly underway or being contemplated. Such a workshop and resulting SOAR should consider all aspects of organisational performance, including a section of practices with maintenance in this workshop.

C.2 Shutdown

The context for operation in low power and shutdown mode is different from power operation. This has been observed as a concern and should initiate further activities. PWG5 should take the lead to make an evaluation based on reports in progress from the currently established task. Further reflection is needed to evaluate the future activities.

C.3 Decommissioning

Group discussion showed a somewhat altered view of how to define decommissioning in respect to Human Performance factors. What is valid in many Member countries is the concern which precipitates from the announcement (or even the potential news broadcast) of a plant shutdown to the time decommissioning begins. It was noted that resources play a key role during this period as well as staff changes (e.g., loss of experienced staff, loss of motivation, etc.). The groups propose NEA to convene an information exchange meeting with interested Member countries in order to discuss areas of concern in this respect and identify possible areas that merit further research and their priorities. This could be a joint undertaking with the CNRA Working Group on Inspection Practices.

C.4 Improvements of Methods for Evaluation of Operating Experience

Operating experience is crucial for research in the Human Performance area. There is a need to check models with real outcome. The database needs further improvement. PWG1 and ETF have strengthened the possibility in IRS to collect experience with Human Factor events. IAEA's coordinated research programme should be checked so that further activities in this area will avoid duplication. NEA should only cover those areas not addressed in the programme by IAEA.

C.5 Validation of Existing Techniques for Human Reliability Analysis

Existing methods for skill and rule based human reliability analysis have several common traits. Member countries should continue to validate these methods against operating experience. The use of simulator data should also be of use in this regard. Such verification and validation should lead to a reduction of uncertainty both in human reliability analyses as well as in the overall PSA results.

C.6 Safety Culture

The group discussions noted this was an extremely important issue, adding it is a topic that has been mainly dealt with by IAEA, through various guides and other documents. It was noted that some work has been done at NEA, through the CNRA Working Group on Inspection Practices. This has primarily involved looking at regulatory evaluation of safety performance of licensees and not directly at human factor aspects. Further work should be directed towards the development of positive indicators for safe organisations. However, before any work starts within NEA, careful coordination should be maintained with the IAEA, (as it was understood the IAEA is giving some priority to this area in the near future). This does not exclude the NEA from performing work on the use of performance indicators of more technical nature.

C.7 Procedures[1]

The verification of computerised procedures may be more complex than that for conventional procedures; in particular, dynamic issues may be more important. In addition to the traditional methods for verifying procedures, integrated simulations of operator and plant response may be useful to: (1) verify that the plant operating procedures can be understood and performed by the operators; (2) verify that the response based on these procedures leads to the intended results; (3) identify potential situations where the judgement of the operators concerning the appropriate response is inconsistent with the procedures; (4) study the consequences of errors of commission and the possibilities for recovering from such errors.

[1] Added after the meeting.

3. REMARKS

1. Based on the various issues reviewed and the subsequent discussions it is quite evident that several of the issues are a higher priority than others. Further work by the PWGs on: Cognitive models and Errors of Commission, workshops and accompanying SOARs on Organisational practices as well as Man-machine interactions. Additionally, the NEA should give some priorities to the area of shutdown and decommissioning. Coordinated actions are proposed for these issues.

2. A major point brought forward is that continued co-operation and coordination between PWG1 and PWG5 of tasks in all of these issues is vital. Going even further, the group noted that it is essential that future work in many of these areas be operated as joint undertakings between the two groups.

3. It was determined that while the programme set out in this report provides strategic planning on the issues of Human Performance over the long term, in order for any plan such as this to be successful it is necessary that there be good coordination with other international organisations as well as individual national programmes in conducting future research.

4. Equally important to coordinate with other organisations is the overall importance that licensee and industry involvement can provide in Human Performance factors. This can and needs to be extended not only within the nuclear industry but to other industries in which similar problems exist. The need to develop better data is a key ingredient in this mix. This can also be reached by promoting human factor training to a large amount of specialists (experience feedback).

ANNEX 1

1. STRATEGY OF RESEARCH WITHIN SESAR PRIORITY NEEDS

Human Cognition - How and Why Human Errors occur? Human Error Analysis, Human Performance Modelling

Canada	Development of a model of operator cognition (normal operation)
Czech Republic	Human reliability analysis in frame of PSA : - quantification of probabilities for human errors, performance shaping factors studies - analysis of human factors contribution to the risk
Finland	Integrated analysis method of accident sequences
France	1. Dependencies and pre-initiator conditions studies 2. Recovery studies, 3. Human factor in fire conditions
Germany	1. Common characteristics of human behaviour 2. Better understanding of performance shaping factors for different areas of human actions 3. Better understanding of cognitive aspects of human behaviour of individual, group and co-operation. 4. Influence of communication on human errors 5. Functional analysis and qualification demands in EPR
Hungary	1. Improvement in HRA models with use of data from varied sources, with integration of human behaviour and human factors concepts into quantitative HRA and with better link between analysis of reported events and HRA 2. Representation of cognitive errors in HRA models, modelling of dependencies between cognitively linked actions 3. Use of feedback from ergonomic studies and HRA in a range of plant modification
Japan	Investigation of characteristics of cognitive behaviour and to develop model for it including error modelling.
Spain	Elaboration of a human error taxonomy for risk analysis
Switzerland	1. Improvement of current HRA methods (e.g. SLIM calibration) 2. Development (in cooperative efforts) of methods for treating decision-based errors, including errors of commission 3. Development of dynamic safety assessment approaches centred on operator-plant modelling
UK	Safety attitude survey, stress and performance study, fault finding Expertise training and aiding for novel and challenging events, detection of latent failure, Nature of violation
USA	Conduct operating event analysis and database maintenance to support Human Performance evaluation and human reliability analysis, develop and update an integrated model of human performance and human reliability

Human Interaction and Decision making under Emergency Conditions

France	Human factors or organisational aspects in accident management conditions
Finland	Diagnostic and decision making in control room during plant disturbance

Evaluation of New Computer-Based Control Rooms, Surveillance and Job Aids

Control Room and Surveillance

Canada	Review of annunciation systems world-wide (state of the art)
France	Problem of interaction between human and automatic systems
Germany	1. Development of methods and tools for assessment 2. Comparison and optimisation of classical, hybrid and computer based control room 3. Functional analysis and qualification demands in EPR 4. Role of participative ergonomics in control room design 5. Balance between automatics systems and human 6. Problem of interaction between human and automatic systems
Japan	1. Advance research on man machine interface 2. Investigation of methodologies for supporting human intellectual activities in nuclear installation under unanticipated conditions 3. Development of methodologies for human reliability analysis and develop human factor database including human error probability data
Spain	1. Advanced Boiling water reactor and AP-600 Human system interface design implementation plans studies 2. Control room design review design ,development, verification and validation of a computerised alarm systems for GE 3. Generation of a Guideline to evaluate Computerised Operator Support Systems, 4. Evaluation of the Safety Parameter Display System of a Spanish Nuclear Power Plant and MMI guideline including Human factors criteria
Sweden	Modernisation of instrumentation and control systems including control room function (maintenance of software, risk analysis of modification in software, organisational factors)
UK	Alarm reduction technique studies
USA	1. Studies and development of a review guidance on the effects of introducing advanced systems into existing control rooms (Hybrid control rooms), 2. Advanced alarm system characteristics and their effects on human performance and develop review guidance

Support Tool

France	Computerised procedure studies
Germany	1. Development of advanced analytical tools to increase reliability of computer based systems and to license computer based systems 2. Further development of computer based operator systems for information, diagnosis, analysis of events, prognosis of events sequences, training 3. Optimisation of procedures and organisational aspect in particular for accident management
UK	1. Inclusion of human factors in design methodologies for major software projects, 2. Evaluation of the suitability of a nominated computer based display system for operating procedure management displays, 3. Developing discriminable and task relevant colour set for computer based displays

Shutdown and Low-Power Conditions: Training and Support Tools

Czech Republic	Shutdown PSA studies
Finland	Maintenance analysis and decision support: - human and organisational factors in non destructive testing - human errors in relation to maintenance activities - human reliability for shutdown conditions
Hungary	Human reliability analysis for shutdown conditions by using a combination of experience feedback and expert opinion

Management and Organisational Performance - Total Safety Management and Safety Culture

Canada	Project to understand and construct a method assess organisation and management in nuclear facilities
Czech Republic	Comparison of PSA for different types of installation ; research, plant, chemistry
Finland	Development of organisational performance indicators , relationship between safety culture and management
Germany	Management and HF reporting
Hungary	Development of methods that better meet the need of analysing event data for the purpose of risk evaluation and risk management.
Spain	Evaluation and modelization of organisation and management influences on the safety
Sweden	1. Nordic research programme for integrated safety analysis 2. Economy/safety Methods for the evaluation of organisation. Evaluation and modelization of organisation and management influence on safety
Switzerland	1. Development of an Interview tool for the identification of the safety awareness of NPP staff 2. Review of qualifications/requirements for licensed NPP personnel (operators, shift supervisors, safety engineer)
UK	Safety culture enhancement programmes
USA	Develop the technical basis and guidance on management and organisational influences in human performance and facility risk (for example staffing aspects

2. OTHER PRIORITIES NOT IN THE SESAR IDENTIFICATION

Procedure

Czech Republic	Detailed analysis of new generation of procedures and development of new generation of emergency procedures
Finland	Modification procedures
Hungary	Introduction of new emergency operating procedures and the associated modified approach to accident mitigation
Spain	Generation of human factor guidelines to be used in the writing, reviewing and approval of power plant procedures
Switzerland	Application of dynamic tools to procedure evaluation

Decommissioning

Sweden	Development of a Knowledge based on Key issues for decommissioning

Competencies and Training

Canada	Evaluation and validity of AECB simulator test based
Czech Republic	1. Addressing PSA result in the training schedule of full-scope simulators 2. Using data from simulators in PSA studies
France	Competence study
Hungary	Use of insights from risk studies for feedback to training
Japan	Investigation of methodologies for supporting acquisition and maintenance of intellectual competencies
Switzerland	Requirements on the competence of NPP operators, shift supervisors and safety engineers

Training on Human Factor Field

Japan	Study on human factors educational methods

Communication with Public

Japan	Evaluation of mutual influence between society /culture and human factor

Specific Activities Studies

Sweden	Non destructive testing from an MTO perspective
Finland	Accident management studies comparative assessment of plant modification

3. STRATEGY OF COUNTRY / METHODOLOGY

Method for Human Factor Events and Operating Feedback

France	Modelization of the methods used during human factor safety analysis, human factor analysis methods and database improvement
Germany	Improvement of HF Reporting Further development of methods and tools: - for HF causes analysis - for prioritisation of HF events - for assess effectiveness of improvement and correctives action in HF areas Development of credible Performance/safety indicators
Hungary	Improvements in event reporting and analysis
Japan	Establishment of database and development of human reduction methods
Spain	Use of different methodologies to analyses human related events
UK	Trend and pattern methodology for human factors roots causes in events
USA	Provide human performance evaluation and human reliability support to inspection and review activities of nuclear reactors and for materials licensees

Risk or Project Analysis Methods

Sweden	1. Review of methods for risk analysis applied in nuclear and other industries 2. Development of a check list for the evaluation of project handbook

4. HALDEN REACTOR PROJECT

Research Activities in Man-Machine Systems Research (some activities)

Hammlab 2000	Installation of BWR and PWR Simulators
Hammlab	Guidelines for control room modernisation
Man-Machine Interaction Research	Development of methods for qualitative prediction of operator performance
Process Surveillance and Operation Systems	Extending the functional modelling framework
Enhancement and Assessment of System Quality	Recommendation on how to compare the use of formal methods with traditional techniques

ANNEX 2

List of Members of the Task Force on Human Performance

Messrs./Mmes. Bareith, A., Hungary
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