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Organisation for Economic Co-operation and Development

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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

NEA/CSNI/R(98)17/VOL2
Unclassified

IDENTIFICATION AND ASSESSMENT OF ORGANISATIONAL FACTORS RELATED TO THE SAFETY OF NPPs

Contributions from Participants

February 1999

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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 Zealand 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 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 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 the NEA 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 co-operates with the NEA Committee on Radiation Protection and Public Health and the NEA Radioactive Waste Management Committee on matters of common interest.

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Volume II

Contributions from Participants

Volume II contains contributions given by the participants at the workshop. It gives an overview on practices and activities in the participant's countries.

Chapter 1 contains an overview on methods used by utilities. Chapter 2 describes methods and the frameworks within they are used by regulators. In chapter 3 the research programs presented at the workshop are described in a structured manner.

The bibliography in Volume II contains the authors referenced in Volume I as well.

Acknowledgments

This report would never had been published without the help of all workshop participants who accepted the strong organisational constraints in the preparation of the workshop and continuously contributed to the state-of-the-art (SOAR) in written contributions and detailed reviews.

The Expanded Task Force (ETF) on Human Factors members would like to express their thanks to all participants of the Boettstein Castle Workshop on Organisational Factors.

Organisation of the report

This report is divided in three volumes:

Volume I

Section I: “Introduction” provides background information on the development of the workshop and how the workshop was organized.

Section 2: “Organisational Factors” provides a description of the twelve factors identified in the workshop.

Section 3: “Assessment Approaches” discusses various methods for assessing organisational factors. (Details on Methods and frameworks used in different countries by utilities, regulators and researchers are presented in Volume II.)

Section 4: “Future Needs” describes research needs to enhance understanding and knowledge of organisational factors and its contribution to human safety performance and risk.

Volume II

Methods and frameworks used in different countries by utilities, regulators and researchers.

Volume III

Appendix II: Papers contributed by the participants.

All bibliographical references appear in both Volume I and Volume II.

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1. UTILITIES

Two representatives from utilities, one from the Canadian Hydro-Quebec (HQ) and one from the French Electricity of France (EDF) described their approaches.

1.1 Canada

Management Oversight and Risk Tree

The MORT analysis which was developed for mainly addressing conventional safety was adopted to scrutinise nuclear safety related events and is used among Canadian utilities. It is a fault-tree approach addressing important management functions supporting certain tasks. It is designed to analyse events but can also be used in a proactive way. It is regarded to be applicable to the assessment of Management Functions and Overview. The most useful aspect of it is its help as a check-list. In the United Kingdom another modification called SHORT-MORT is in use.

Human Performance Enhancement System

Another tool called Human Performance Enhancement System (HPES) is applied in most Canadian utilities (the same goes for the majority of utilities in the United States). The method is used for event analysis. Although it never has been done so yet, it seems to be worth trying it as a proactive regulator tool.

Root Cause Analysis

Another approach was presented in a distributed paper based on the analysis of around hundred very minor events within a period of one year. The root causes of these minor events were classified according to the following five families:

- overview and decision making
- communication
- organisational clarity
- human resources management
- culture.

All the families contain a dozen of key indications which should be chosen to describe the event.

The statistical analysis of these root causes gives a picture of the more frequent factors which appear in events and disturbances. This method is a kind of proactive method because the analysis of very minor events may indicate major deficiencies in organisation which could be root causes of more important events.
This data collection and the analysis are performed by a small crew of four persons in the Gentilly-2 plant. Further details can be found in Loiselle (1998).

1.2 France

The Nuclear Inspection Department of the French utility Electricity of France (EDF) has the mission to make a global evaluation of the nuclear safety. For that purpose, this department has developed an audit method which takes into account organisational factors. This approach was tested and is systematically used since 1995 on all nuclear power plants. Each plant is reviewed by EDF staff from the Nuclear Inspection Division every second year.

Global Evaluation of Organisational Factors

In order to evaluate the effectiveness of the organisational structures (i.e. sharing tasks and responsibilities, explicit (on paper) and implicit (real) organisation, observed behaviour of individuals and groups executing their tasks) the following aspects are reviewed:

- Organisation of safety management : policy, organisation, implementation.
- Operation organisation: Management, training, overview and control, operation practices, programme for future improvements, documentation.
- Maintenance organisation: management, training, programme for future improvements, quality of intervention preparation, co-ordination, intervention practices.
- Transverse aspects: engineering aspects, auditing and reviewing of activities, operational feed back analysis, modifications.
- Radioprotection aspects: management training, measure analysis, quality of preparation, radioactive source management, logistic control.

The following questions illustrate the type of investigation of EDF inspectors:

About site management: Is the site management only interested in developing work rules and procedures, or is it also interested in developing work values that are common to both the staff and the management? Does management consider both individual and group inputs for each different task? Are task requirements defined with the participation of the employees involved in the task in order to develop a referential that is common to both management and the employees?

About procedures: Are procedures, standards, and rules taking into account the characteristics of the employees, their skills, personalities, and individual and group goals? Are documents that support work (procedures, instructions, etc.) improved, complete, and do they contain sufficient details according to the needs of the users? Is operating experience feedback developed to ensure that developers and users of various rules and instructions are in agreement with the intent of these rules?

About resources allocation: Does the assignment of personnel to various tasks consider the individual employees' particularities (level of experience) and not only their « administrative » certifications?

The techniques used during these audits are documentation analysis, close observation of the field activities and interviews in order to complete the task observations. These interviews provide information about the causes of identified discrepancies.

After such an evaluation, the evaluated site has to define an appropriate way for improvements and has to take precise engagements for the deadlines of the proposed improvements.

The resources needed for each evaluation are the following :

- The **evaluation team** consists of about 20 members: 10 are Inspectors from the Nuclear Inspection Department and 10, so called « peers » that are coming from different nuclear sites. They meet together with approximately fifteen local delegates from the nuclear sites.
- Four weeks for preparation: All data concerning the nuclear safety of the evaluated site are collected and analysed. A report is written with the defined specials concerns. The last week of preparation includes a 3 day meeting with the complete evaluation team.
- Two weeks (10 working days) for evaluation on site.
- Four weeks for analysis and preparation of the final report. During this phase the results of the evaluation are transmitted to and discussed with the management of the evaluated site in order to make sure that the causes of the discrepancies are well identified and understood.

The main limitation of this approach is the duration of observations on site. Only two weeks are very often not long enough time for an in-depth observation of all organisational factors and especially for determining the causes of discrepancies. Because of the limited duration, the site management staff sometimes considers observations as not completely representative.

However, the general frame of nuclear safety level used for these evaluations appears very appropriated for the improvement of organisation.

In addition, one OSART Mission is conducted every year in one or two EDF plant.

1.3 Spain

The Spanish utilities (UNESA), in collaboration with the Spanish Nuclear Regulatory Body (CSN), and CIEMAT have started a five-years R&D project, entitled «Development of methods for evaluating and modelling the impact of organisational factors on nuclear power plants safety» (see chapter 3.3 for the project description).

1.4 Switzerland

In the framework of a self-assessment some Swiss NPPs have conducted reviews by an external consultant company in order to identify potentials for improvements of organisational performance.

2. REGULATORY BODIES

The largest sample of representatives at the workshop came from regulatory bodies and inspectorates. Even among this more or less homogenous group one can find very different approaches.

For each country given in the alphabetic order, first, the context and the framework will be presented, then the assessment approaches.

2.1 Canada

2.1.1 Context and Framework

In recent years, analysis of "high profile" incidents both within as well as outside the nuclear industry have focused attention on the importance of organisation and management factors in the etiology of incidents. Most of these data highlight the negative effects on safety culture of "poor" O&M (e.g. TMI, Chernobyl, Herald of Free Enterprise, Piper Alpha, etc.), although we should not forget that there are positive lessons to be learned from organisations with robust safety cultures (e.g. the way in which Sunoco, an Ontario based oil company, dealt with a major fire, caused by a lightning strike, at its Sarnia refinery in 1996).

Nuclear Safety is predicated on the concept of "defence-in-depth". All of these defences, however, rest on an O&M foundation. AECB Staff believe that if that foundation is flawed, then there are potentially serious problems for the entire defence system. To monitor the effectiveness of licensees' managed processes on achievement of the nuclear safety goal, the AECB has established a set of objective performance indicators. One such indicator utilises data from Significant Event Reports (SERs).

Canadian Licensees are obliged to provide the AECB with Significant Event Reports (SERs) about certain incidents which occur within their facilities. The AECB maintains a database of information, including cause categories, pertaining to these events. The graph displayed in Figure 1 below shows the number of times each category has been identified as a causal factor in the event database. As can be clearly seen, Human Performance causes are the most prevalent.

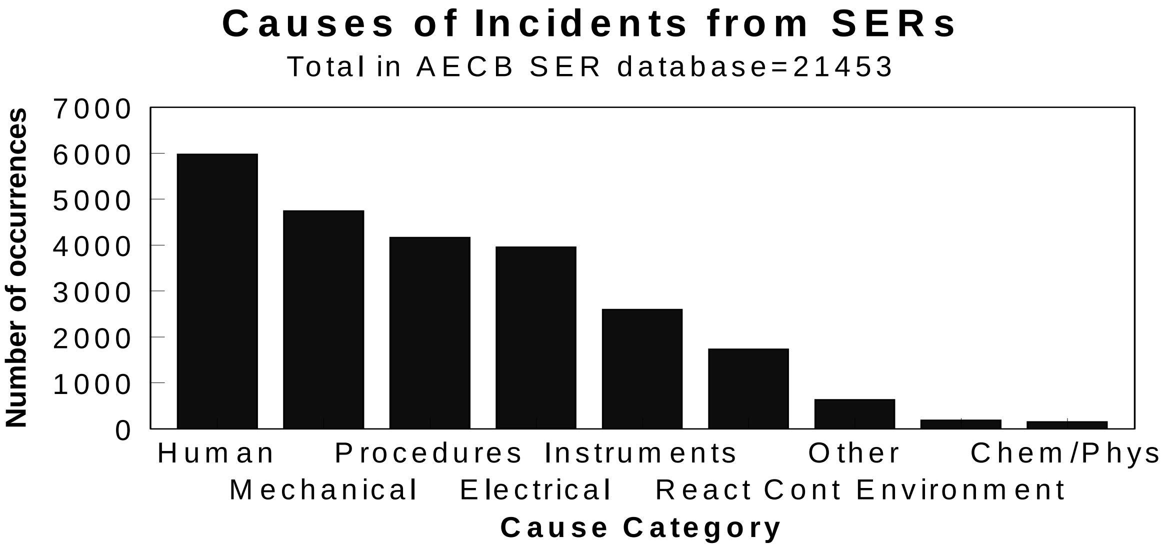

Figure 1

Figure 2 shows trend plots of the percentages of events in each cause category of the database for the fourteen year period from 1982 to 1995. Interesting points are that the contributions to the total database from Instrument , Electrical and Reactor Control causes have reduced over the period, however, the contribution from Human causes has increased. Although there are many possible reasons for this change in the shape of the database over time, it was clear to AECB Staff that there is an urgent need to address the Human issues involved in the significant events.

For the reasons discussed above (the growing realisation of the importance of O&M on safety and the "track record" as evidenced from event data) AECB management decided that a proactive approach was required to develop a systematic, objective process for assessment of licensees' organisation and management. In 1996 the AECB embarked on a three year project to develop an O&M assessment method which can be used by AECB staff as part of the normal regulatory process. Although the envisaged product is primarily for AECB staff use, it will be freely available to licensees who, it is anticipated, will also make use of the method for self assessment purposes.

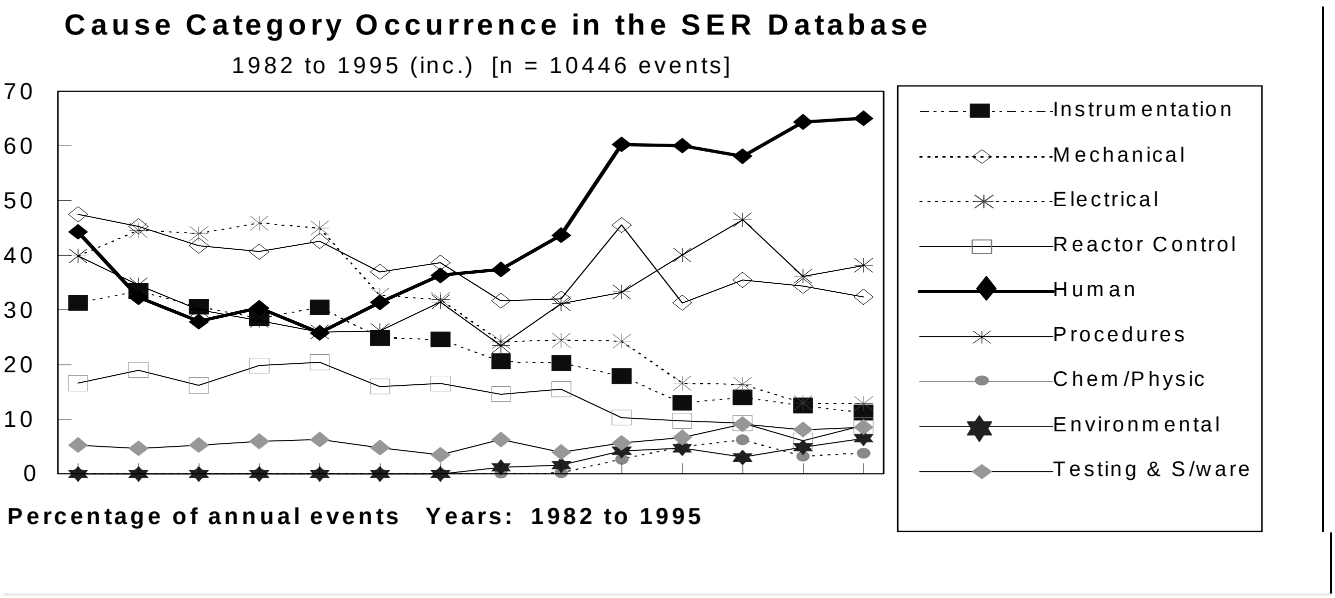

Figure 2

2.1.2 Method and Approach

2.1.2.1 Project Strategy

- Retain world class consultant

Expert consultants, Human Performance Analysis, were retained to undertake the research and development work involved. These consultants, under the direction of Dr Sonja Haber, have extensive experience in the subject area having conducted similar work for the US NRC which resulted in the successful development of an assessment method called NOMAC.

- Use validated techniques

AECB Staff believe that any techniques used in the overall method must have a solid track record gained from having been well-tried, tested and accepted by the nuclear community.

- Consult with stakeholders

Consultation with stakeholders is essential throughout the course of development of the assessment method to ensure that the end-product meets the needs of the users and is accepted by the licensees in our non-prescriptive regulatory environment.

The major stakeholders were identified as being:

- AECB staff
- Licensee organisations

- Fieldwork with licensee organisation(s)

The method must have been successfully tested in a real environment prior to acceptance by AECB as a part of the regulatory process.

- Pilot study

The complete assessment method must be successfully demonstrated in a Regulatory Pilot Study. This must identify where the method can be used by "non-experts" and where „expert specialist“ resources are necessary to produce consistent and reliable assessment data. These data must be subjected to analysis and a standard format regulatory report (termed a Board Member Document) produced. The result of this phase of the project will determine whether the method is deemed acceptable for inclusion in the regulatory process, or whether additional research work is required.

- Modify and roll-out

- Monitor and adjust (long term)

2.1.2.2 Methodology Development

The model used in the development of the assessment method has been termed the Canadian Adaptive Machine Model (CAMM). It is based on the principles of the US NRC's NOMAC, suitably modified for the Canadian nuclear environment. The ultimate purpose of the method will be to assess Licensees O&M systems and processes as a standard component of our formal regulatory process.

This will apply to all aspects of the nuclear life cycle (research, design, uranium mines, fuel fabrication, power reactor operation and decommissioning). Although the work done to date has largely been carried out in a "research" context, we have already had the opportunity to carry out a field trial of the methodology in its entirety at one nuclear power plant. Additionally, AECB Staff have used some tools from the methodology in three actual regulatory assessment activities. Two of these were associated with licence renewals for a uranium mine and for a nuclear energy research site. The last involved assessing a major nuclear power generation licensee’s reorganisation proposals.

2.1.2.3 Prerequisites

A number of prerequisites for the method were specified. These were:

Objective Measures: It was considered important that the techniques chosen rely on structured and objective observations and not subjective judgements. One criticism of many investigations into the area of organisational performance has been that the results of the investigations are not replicable due to the large degree of subjective judgement inherent in the methodology used for conducting the investigation. By providing methods that are more objective, the collected data and any conclusions drawn from the data are more defensible, replicable, and allow for comparative analysis (either over time at the same organisation, or across organisations).

Quantitative and Qualitative: Both a quantitative and qualitative assessment of the organisational dimensions under study is important for an adequate understanding of organisational performance. Specifically, quantitative data provides objective measures of the dimensions under study while qualitative data allows for descriptive statements which help in the characterisation of the quantitative assessment.

High Scrutiny and Use: Because the methods are being developed for regulatory application, the methods chosen must be able to withstand substantial peer scrutiny and must have undergone extensive use.

The methodology must be capable of being continuously refined and adjusted to be effective in the variety of situations which the AECB regulates (e.g. NPPs , Mines, Fuel Fabrication, Isotpoe Production, Decommissioning, etc.).

Documentation: standards, criteria and processes must be clear and unambiguous to both assessors and licensees. Also, the documentation produced must create a traceable history over the long periods of time associated with organisational/cultural issues.
The method should be as non-resource intensive as possible.

The method must focus clearly on NUCLEAR SAFETY requirements. The adoption of any particular management philosophy is the prerogative of the licensee, however, the AECB must be satisfied that the approach adopted is conducive to ensuring nuclear safety. The assessment method must therefore be able to provide accurate assessment data regardless of the prevailing organisation and management style.

There is a requirement to develop baselines for individual facilities against which the AECB can return some time later and identify the effects of change. The method must be sensitive to this requirement. In addition, the method must provide the AECB with the ability to compare one facility against another in a consistent and valid manner.

Safety vs Production and Quality: Although the primary interest of the AECB is Safety, we cannot ignore the impact of our regulatory requests on licensees Production and Quality goals. The assessment method must give us insight into this.

Sensitive to needs of all groups: although the method must assess Organisation and Management this does not mean that focus is only on the "management" group. It is essential that the AECB understands the effects on safety of the management process from top to bottom and across all levels of the organisation. The assessment method must allow us to identify this.

2.1.2.4 Focus Areas

High Reliability Culture: From recent international level work done in this area we are beginning to be able to accurately describe high reliability culture characteristics. We believe this to be a focus area of particular importance as we move more into a "risk based regulation" environment.

Creativity vs Proceduralization: Traditionally nuclear facilities have focused on Proceduralization. We know from experience, however, that this is no guarantee of nuclear safety. Analysis of human action continuously reveals a tendency towards Creativity which we cannot, and should not, eliminate. AECB Staff believe, that control can only be fully achieved through an appropriate "balance" of proceduralization and creativity so as to enhance, rather than detract, from nuclear safety. The AECB must therefore be able to measure and assess how successful nuclear organisations are in achieving this.

Task Complexity - what do we mean by this and how can we measure it.

Organisational layering and shifting roles - an example here is "Teamwork" and how its introduction can affect the more "traditional" systems of work.

Communications - almost a cliché -but it is vital that we understand them.

Organisational flexibility - how does the organisation respond to the changing environment.

2.2.2.5 Factors Assessed by the Method

The factors (or dimensions) which we assess are as follows:

Centralisation:
Centralisation refers to the way decisions that affect the operation of the facility are made and who makes those decisions. Particularly, the degree to which decisions are made within a small circle of high ranking individuals versus decisions made by many, at all levels of facility operations.

Coordination of Work:
Coordination of work refers to the planning, integration, and implementation of the work activities of individuals and groups.

External Communication:
External communication refers to the exchange of information, both formal and informal, between the facility, its parent organisation, and external organisations (e.g., AECB, the public).

Formalization:
Formalization refers to the extent to which there are well-identified rules, procedures, and/or standardised methods for routine activities as well as unusual occurrences.

Goal Setting/Prioritisation:
Goal setting/prioritisation refers to the extent to which facility personnel understand, accept, and agree with the purpose and relevance of goals.

Interdepartmental Communication:
Interdepartmental communication refers to the exchange of information, both formal and informal, between the different departments or units. It includes both the top-down and bottom-up communication networks.

Intradepartmental Communication:
Intradepartmental communication refers to the exchange of information, both formal and informal, within a given department or unit. It includes both the top-down and bottom-up communication networks.

Organisational Culture:
Organisational culture refers to facility personnel's shared perceptions of the organisation. It includes the traditions, values, customs, practices, goals, and socialisation processes that endure over time and that distinguish an organisation from others. It defines the "personality" of the organisation.

Organisational Knowledge:
Organisational knowledge refers to the understanding facility personnel have regarding the interactions of the organisational subsystems and the way in which work is actually accomplished within the facility.

Organisational Learning:
Organisational learning refers to the degree to which individual facility personnel and the organisation, as a whole, uses knowledge gained from past experiences to improve future performance.

Performance Evaluation:
Performance evaluation refers to the degree to which facility personnel are provided with fair assessments of their work-related behaviours. It includes regular feedback with an emphasis on improvement of future performance.

Performance Quality:
Performance quality refers to the extent to which facility personnel adhere to their job requirements, carry them out correctly, and take personal responsibility for their actions and the consequences of those actions.

Personnel Selection:
Personnel selection refers to the degree to which the organisation effectively identifies and selects personnel who can meet the demands of the job and the degree to which the facility has personnel who can perform both the routine and unique aspects of their positions.

Problem Identification:
Problem identification refers to the extent to which the organisation draws upon knowledge, experience, and current information to identify potential problems.

Resource Allocation:
Resource allocation refers to the manner in which the facility distributes its financial resources. It includes both the actual distribution of resources as well as individual perceptions of this distribution.

Roles and Responsibilities:
Roles and responsibilities refers to the degree to which facility personnel's positions and departmental work activities are clearly defined and carried out.

Safety Culture:
Safety culture refers to the characteristics of the work environment, such as the norms, rules, and common understandings that influence facility personnel's perceptions of the importance that the organisation places on safety. It includes the degree to which a critical, questioning attitude exists that is directed toward facility improvement.

Time Urgency:
Time urgency refers to the degree to which facility personnel perceive schedule pressures while completing various tasks.

Training:
Training refers to the degree to which facility personnel are provided with the requisite knowledge and skills to perform tasks safely and effectively. It also refers to facility personnel's perceptions regarding the general usefulness of the training program.

2.2.2.6 Tools Incorporated

The following tools, all previously validated, were incorporated into the method:

Functional Analysis - This method provides a description of the organisational workflow. Data to implement this method is obtained primarily through documentation review, interviews, walk-throughs, talk-throughs, and some observation of organisational activities such as meetings.

Structured Interview Protocol - This tool is a standardised database of questions, built from many different sources, all of which deal with the impact of organisational factors on safety performance. While not all questions are asked of each person interviewed, this methodology allows the organisational investigator to select relevant questions from a previously established database to assess pre-identified issues. This methodology makes it possible to address the organisational dimensions of relevance based on hypotheses formulated from the model.

Behavioural Checklists - Behavioural Checklists have been utilised by a variety of researchers of organisational issues (11,12). Based on the organisational dimensions identified as important for assessment from the model developed, key behaviours are identified which are representative of the dimensions and which are readily observable. The key behaviours were identified based on issues identified by the model as well as from the expertise of individuals with extensive background in the investigation of the impact of organisational factors on safety performance.

Behavioural Anchored Rating Scales (BARS) - BARS are performance evaluation devices that incorporate behavioural examples with general performance dimensions. Specifically, each scale or BARS represents one area of performance or one organisational dimension. Each BARS contains a definition of the dimension and a 5-point scale, with behavioural statements anchored to each point. The behaviours act as "anchors" for defining the various levels of that dimension.

BARS are generally thought to be a superior technique to traditional rating scales (i.e., 1 = poor, 5 = excellent) for the collection of information related to organisational performance.

Survey Techniques - The use of this technique allows data to be collected using a well-developed standardised questionnaire to assess various aspects of organisational factors. The particular survey that is proposed for use in this project allows an assessment of both organisational and safety culture and has been implemented across a variety of high-risk industries.

2.2.2.7 Current and Future Work Plan

Our experience from the 1996/97 field trial was very favourable, to the extent that another year's funding has been approved to complete the development of the method as a standard regulatory "tool". Particularly important was the feedback from the licensee whose organisation and management was assessed. Although pointing out areas where further development work is required prior to total acceptance, the licensee agreed that the process was systematic, fair and, most importantly, provided valid data resulting in an accurate assessment. (This is particularly important because of the non-prescriptive regulatory process used in Canada).

In the three instances where parts of the methodology were used to provide information in support of regulatory decisions, those assessments were reported to have made valuable contributions.

The 1998/99 research plan comprises of the following four major activities:

- Development of organisation and management "standards" for the Canadian nuclear industry.
- Field trial of the finalised assessment method against the "standards" in at least one nuclear facility.
- Develop a regulatory protocol for organisation and management assessment
- Train AECB staff and commence implementation.

The first of these activities, Standards Development, is already well under way. It has involved consultation with licensees in a series of "workshops" to define and agree on what can be classified as "minimally acceptable" for a comprehensive set of factors which affect organisation and management.

The Field Trial will be done at a multi-unit NPP station. It will result in the preparation of a Board Member Document (BMD).

With regard to the development of a formal Regulatory Protocol for routinely carrying out O&M assessments, it is extremely important that this method is used, and seen to be used, as a **component** our integrated regulatory assessment process. How we do this will require clear and precise stipulation, systematic and controlled implementation, and regular follow-up monitoring.

An appropriate training programme for AECB Staff will be developed following a Systems Approach to Training (SAT).

2.2 Finland

2.2.1 Context and framework

Finland's nuclear power plants are located on the south and west coast of Finland. The state-owned Imatran Voima Oy (IVO) operates two 445 MW VVER-440 type pressurised water reactor units (Loviisa 1 and Loviisa 2) near the city of Loviisa. On the west coast of Finland Teollisuuden Voima Oy (TVO) operates two 710 MW ASEA-ATOM type boiling water reactor units (TVO I and TVO II) in Eurajoki. Both utilities are currently (summer 1998) involved in the process of increasing the electrical output of their stations. These four reactors generate about 30 % of Finland's annual electricity needs.

Regulation of the use of nuclear energy in Finland is based on the Nuclear Energy Act (990/87) and regulation of the radiation practices on the Radiation Act (592/91). Further requirements are given in Nuclear Energy Decree (161/88) and the Decision of the Council of the State «General Regulations for the Safety of Nuclear Power Plants" (395/91). According to the legislation the Finnish Radiation and Nuclear Safety Authority (STUK) sets safety requirements and verifies compliance with them. STUK has in this respect developed a comprehensive set of safety guides, the so called YVL-guides.

The object of regulating radiation practices is the use of radiation and radioactive substances in health care, industry, research and teaching. A safety licence in accordance with the Radiation Act is mandatory for the use of ionising radiation. The licence is granted by STUK. Before a decision on granting a licence is made, the applicant must demonstrate that the place where the radiation is used, the sources of radiation and the protective equipment meet safety requirements. Wherever radiation is used, there shall be nominated a person responsible for radiation safety as well as competent staff.

The regulation of nuclear power plants covers the entire life cycle of each facility, from design all the way to decommissioning. The primary objective of regulation is to ensure that the reactor remains under control in all conditions.

The operating organisations have a full and undivided responsibility for the safety of nuclear power plants. In accordance with defined inspection programmes, STUK verifies that their operations and related support activities are appropriate and in compliance with safety requirements.

STUK emphasises the significance of the users' voluntary work in ensuring the safety of their practices. A sound safety culture is built through knowledge, training and motivation. According to STUK's approach it would mean failure if shortcomings had to be rectified by enacting compulsory measures.

2.2.2 Methods and approaches

The YVL-guides provide a basis for the regulatory activities performed by STUK. The guides cover all the main areas of nuclear power plant operation giving instructions and recommendations e.g. on general safety principles, quality assurance, reporting, documentation, personnel qualification and training, outages, plant modifications, inspections and safety assessments, nuclear fuel management, utilisation of operational experience, safety classification, accident analyses, PSA, fire and radiation protection, and emergency preparedness. The YVL-guides are regularly updated to reflect new experience.

Each Finnish nuclear power reactor is refuelled once a year, and at the same time the entire plant is overhauled. STUK reviews the respective plans and assesses the technical upgradings which are carried out to increase safety and reliability. The results of the work are inspected before the plant is restarted.

STUK has been very active in the field of safety culture since the beginning of 1990s when the concept of safety culture was formally included in the Finnish nuclear safety regulations. Finnish experts were also involved in drafting the INSAG-4.

After the Decision of the Council of the State had entered into force in 1991, STUK conducted detailed assessments and prepared Safety Evaluation Memorandums for both TVO and IVO power plants. In the memorandums following topics were addressed:

1. Past decisions of the corporate and plant management where it had been necessary to make a choice between the options of shutting-down the plant (or extending the outage) for acting on a certain safety concern, or continuing operation and taking actions later (e.g. during the next scheduled outage).
2. General housekeeping activities at the plant, and tolerance to minor disorders such as small water or oil leaks in non-nuclear safety systems.
3. Resources invested in maintaining a high level of safety: personnel, external technical support, work spaces and tools, spare part and material storage.
4. Efficiency of the management system ensuring the implementation of approved plans and procedures.
5. Co-operation and information exchange between organisational units.
6. Methods for maintaining and upgrading plant personnel’s professional skills and knowledge.
7. Adequacy and current status of the safety relevant plant procedures, and regard given to those procedures in daily work.
8. Rewards to the plant personnel for good performance and attitude to human errors.
9. Preparedness of the plant management to be subject to an assessment of their own performance, and their attitude to critique.
10. Individuals’ attitude to their duties and problems encountered in various tasks.
11. Openness in uncovering and solving problems.
12. Systematic assessment and development of plant safety.
13. Resources invested in safety relevant plant modifications and research.

2.3 France

2.3.1 Context and Framework

In France, there is only *one* utility for power generation, (Electricity de France, EDF) running about nineteen nuclear sites with fifty seven nuclear power units (all pressurised water reactors having a very similar design). Other nuclear installations concern research and fuel reprocessing units.

The safety authority is the DSIN (Direction de la Sûreté des Installations Nucléaires), the regional inspectors are part of the DRIRE (Direction Régionale de l'Industrie, de la Recherche et de l'Environnement). The IPSN (Institut de Protection et de Sûreté Nucléaire) is a research institute which supports DSIN and DRIRE in their regulatory activities.

For many years, the DSIN and the DRIRE have organised inspections on plants where different issues in the human factor area and organisation are reviewed in detail :

- training process (EDF members and sub-contractors),
- outage activities (maintenance tasks, periodic tests, start-up tests, radioprotection issues, sub-contractor quality assurance).
- documentation quality with emphasis on operation documentation

In addition, if events or inspections reveal organisational deficiencies, specific inspections are performed in order to evaluate the seriousness of the deficiencies.

For the general framework , a legal guideline (Arrêté qualité du 10 Août 1984) describes more or less the main aspects of NPP's organisations. Within this framework, detailed below, all nuclear utilities have to be prepared to be inspected on organisational issues by DSIN and DRIRE inspectors.

More specifically, when the nuclear installations inform the safety authorities of changes in the roles and responsibilities of units, or when a new role is created, DSIN ask IPSN for an in-depth analysis of this policy or commitment change.

For example, in the past, IPSN has made some safety analyses about organisation changes :

- Safety Organisation of the research institution in France,
- new maintenance organisation in 1990,1992 and 1993 (Baumont, 1995).
- new organisation of operating teams from 1993 through 1995 (Charron & Tosello, 1995).
- Subcontractor organisation (ongoing).

In parallel to these safety analyses, IPSN carried out ergonomic studies on site to complete their analyses. The method used is described in the appendix. New reviews on the same issues or on new organisation changes could be planned again.

In the next few years, the new organisation changes which are going to analysed are the following :

- Human factor specialist systems on the plants

- The decentralisation process from EDF head-quarter to plant management

During the years after the implementation of the changes, the result of such change are inspected issues by DSIN and DRIRE.

All these inspections (usually one day, rarely two days, with an average of three people) are done on site and include document reviews, interviews and observations. IPSN experts participate actively in these inspections.

2.3.2 Methods and approaches

The main reference in France for organisation audits is the legal guideline «Arrêté qualité du 10 Août 1984» which prescribes the requirements to ensure design, construction and operation quality for the safety of nuclear installations. This legal guideline describes in seven chapters the main elements in a nuclear installation's organisation, which are summarised below:

Chapter 1 gives «general provisions» in three articles:

The first article mandates how to construct a system:

- to define the quality of the structures, equipment and components, the quality of the systems which associate them, and the quality of the operating conditions,
- to ensure that a system is organised to define the quality of the above-quoted elements,
- to implement and maintain this quality, to verify it and to analyse and correct discrepancies,
- to plan activities based on procedures which come from documentation records.

The system begins at the conception step of the installation and is completed during the entire life of the installation.

The second article prescribes how to identify activities which influence the quality of the above-quoted elements.

The third article defines who is responsible for the utilities and define what a sub-contractor is.

Chapter 2 defines the responsibilities of utilities and subcontractors, the prescription of their relationship and the monitoring of subcontractors.

Chapter 3 gives the general principles for the organisation and the requirements to obtain and maintain the quality which influences safety:

The performance requirements have to be defined for each activity which influences the quality.

For these activities, the technical and human resources have to be adapted to the quality defined, the skills and the abilities of personnel have to be adequate for the activity, taking into account their nature and their influence on safety. Technical tools have to be qualified. For each activity, the organisation has to identify the missions and the duties of the concerned personnel or units and their relationship to each other.

A system is developed and implemented in order to ensure the technical control of each quality based on performance requirements and to control the result of activities, in order to ensure that corrective and preventive measures have been identified and implemented after events or detection of discrepancies.

> A system is in place for verifying implementation of the above requirements. The persons in charge of this system have to be sufficiently competent in technical aspects, have to be independent of the operational managers and have to refer to persons with authority in quality implementation. Inquiries and verification through samples have to be organised periodically. This verification is both for technical aspects and organisation. This system ensures that the means are implemented to draw lessons learnt from abnormal situations and to initiate remedial actions.

Chapter 4 is related to documentation on activities and describes in detail which type of document have to be established, updated, and used. The storage, protection and accessibility conditions are mentioned as being important.

Chapter 5 concerns events and anomalies. Criteria for such anomalies have to be defined as well as reporting conditions and necessary documentation on these anomalies.

Chapter 6 gives requirements about particular items such as studies carried out on safety aspects.

Chapter 7 explains the implementation modalities of this legal guideline.

This legal guideline which surveys a many organisational factors, associating them in a specific order, gives the main axes of the approaches for the assessment of organisation as a whole or on specific aspects. Depending on the problems encountered in events or during inspections, the main details given in an article or in one or several chapters can help to build a particular assessment method.

In this legal guideline, some important organisational aspects are not well developed, such as co-operation, transfer of information, management duties, time allocation. The importance of these factors have been investigated in IPSN studies, based on the activity observation at the plants.

In addition, IPSN is trying to improve the methods used in order to evaluate the organisation as a whole based on the results of past studies. In addition, a bibliographical review has been completed.

2.4 Germany

2.4.1 Context and framework

In Germany, 19 units (BWRs and PWRs) on 14 sites are being operated by various licensees. Pursuant to Section 24 the Atomic Energy Act AtG is implemented by the responsible authorities of the federal states («Länder»)of the Federal Republic of Germany (FRG) on behalf of the Federal Government. I.e. the «Länder» of the FRG are in charge of licensing and supervising the units on their territories, and of ensuring that the safety requirements are met. Lawfulness and expediency of the decisions taken by the «Länder» (i.e. the consistent application of rules and regulations, norms and standards as well as of the state of science and technology) are subject to federal supervision by the Federal Ministry of the Environment, Nature Conservation and Reactor Safety (BMU). Licensing and supervising authorities are assisted by expert organisations and commissions.

The German regulations do not only cover technical aspects, they also address human factors, training and organisational issues. The organisation implemented by the licensees is required to assure safe and reliable operation. Although no particular organisational structure is prescribed, all German utilities implemented the same type of structure (except minor differences). Specific sectors of nuclear power plant organisations are regulated in detail, e.g.:

- operator qualification and training,
- organisation, performance and documentation of maintenance tasks and of radiation protection measures,
- operating experience reporting, analysis and feedback, which is an important part of organisational learning.

Organisational factors have always been taken into account in the analysis and feedback of operating experience. In response to particular events the licensing and supervising authorities e.g. imposed changes in the organisation of the plant concerned.

Main principles of safety culture have always played a major role in the German nuclear industry. Among them are e.g.:

- high priority of safety,
- clear definition of responsibilities and tasks,
- blame-free response to human error etc.

Personnel of the licensing and supervisory authorities and of technical inspection agencies (TÜVs) frequently inspect nuclear power plants. Particular tasks related to nuclear safety like e.g. periodic tests have to be carried out in the presence of such inspectors who have to control the correct and assess performance of these tasks and their outcomes.

Human and organisational factors can be included in these inspections in order to detect deficiencies and early signs of degradation. Results are fed back to the utilities for further investigation and improvements.

The German utilities have implemented a so-called «Human Factors System» which allows to identify and to analyse deficiencies and/or event causes not only in the human factors but, to some extent, also in the organisational domain. For some utilities, OSART missions and WANO peer reviews were carried out.

2.4.2 Methods and approaches

Because of the increased relative importance of human performance for the safety of nuclear power plants, supervising authorities, independent experts and licensees have strengthened their commitment to this subject since years.

Although there was and is no reason to call in question the licensee's organisation in general, the experience gained from the evaluations of operating experience, OSART-missions, results of probabilistic safety analyses, findings of investigation of events and occurrences often show how to further improve the licensed plant condition, including organisational factors.

Accordingly licensees installed the so-called Human Factor System (HF-System) in 1996. In this system, a systematic root cause analysis is applied to operating events and other occurrences to determine those human factors (including organisational, technical and personal factors) that caused or contributed to an error.

A person on site is in charge of Human Factors issues. He/she is required to have a good knowledge of the plant and additional qualification particularly in the following areas:

- root cause analysis,
- ergonomics,
- psychological factors related to work,
- in interviews and observation techniques,
- documentation and reporting etc.

This person is integrated in the organisation of the licensee and is supported in his work by other persons e.g. from the operation and maintenance area and gets the necessary information after an event.

All reportable events of the plant are studied in detail. Events which did not occur in the plant itself are analysed whether there is an influence of human actions and whether it is transferable and applicable, to the licensee’s plant(s).

Further inputs to the HF-System are hints and information about occurrences and possible week-points in organisation, technical equipment and human actions, which are voluntarily reported by the plant personnel themselves. It is also possible that independent technical experts which carry out on-site inspections on behalf of the supervising authority can feed the HF-System with information obtained by walk throughs, document reviews and observation of periodical testing.

If there is an influence of human failures, the following points will be analysed:

- what are the reasons for the incorrect actions, and
- are there possibilities to improve the organisation, procedures, technical devices, etc., to reduce the probability of incorrect actions?

This is done by using proven methods according to the state of the art (for example interviews, observations, document reviews, simulations).

By order of the supervising authority for the nuclear power plants in Bavaria the TÜV Energie und Systemtechnik GmbH, Munich evaluated the usefulness of the licensee's HF-System. The evaluation of the HF-System shows that it is a necessary complement to the already existing activities of the licensees. It will also contribute to optimise organisational factors and to prevent occurrences and events in the future.

An appropriate implementation of the HF-System within the licensee's organisation is crucial, because it determines whether important safety-relevant organisational deficiencies can be found out or not. The supervision by the supervising authority focuses not only on the licensee's actions based on the HF-System, but also covers all the licensee's actions and measures that are relevant to human performance and to some extent, organisational factors.

This HF-System is under continuous improvement according to practical needs and experience.

2.5 Spain

2.5.1 Context and Framework

The Spanish Nuclear Regulatory Body (CSN), the Spanish utilities (UNESA) and CIEMAT have started a five-years R&D project, entitled «Development of methods for evaluating and modelling the impact of organisational factors on nuclear power plants safety» (see chapter 3.3 for the project description).

2.6 Sweden

2.6.1 Context and Framework

At present, in mid 1998, there are 12 nuclear power units, 9 BWRs and 3 PWRs, in operation in Sweden. There are four licence holders and two dominating owners with large shares of the electricity market. The NPPs employ altogether about 3 500 persons.

The Swedish Nuclear Power Inspectorate (SKI) exercises supervision in compliance with the Act on Nuclear Activities. According to the Act the licensees have the full and undivided responsibility to take all measures necessary to achieve safety. SKI shall define the detailed purport of this responsibility and supervise how the licensees execute it, by creating its own well-founded view on the safety status of the installations and on the quality of licensee safety work. The more detailed mission objectives of SKI include to provide a clear definition of requirements, check compliance with requirements by supervision focusing on organisational processes and activities, initiate safety improvements and maintain and develop competence at licensees, SKI, and nationally. The regulatory strategy thus prescribed assigns equal weight to technical and organisational factors influencing safety and that regulatory inspection and supervision efforts should largely focus on the quality of plant safety management.

After the TMI-2 accident, the Swedish Government set up a special Committee which recommended a substantially reinforced and more co-ordinated programme on human factors, both with regard to regulatory and research activities. As the programme developed, the term "human factors" (or "man-machine" as was the concept used) was found somewhat inadequate to describe the programme and the issues addressed. The programme was thus renamed as addressing the interaction between Man, Technology and Organisation, MTO for short. Specified areas within the MTO-programme included organisational issues and safety culture, quality assurance, competence and training, control room work and design, procedures, maintenance, incident- and risk analysis.

The MTO-group at SKI, consisting of five behavioural scientists, in the beginning of 1990s worked out tools for inspection in the areas of maintenance programs, quality systems and assessment of the learning processes of an organisation. The group is currently deeply involved with inspections and reviews which are performed in mixed teams with the technical and engineering staff of the Inspectorate. In addition, long term research and development programmes concerning new knowledge and criteria to be used in SKIs reviewing of new technical and organisational solutions at NPPs are on the agenda.

In 1998 new general safety regulations have been issued for nuclear installations. The regulations are supplemented with general recommendations on their application. Some of the provisions are the same as applied earlier but on a number of issues the requirements have been extended and reinforced. This applies in particular to human factors and organisational issues. New or reinforced requirements are thus issued on for example the licensees responsibility to

- provide working conditions supporting safe behaviour
- provide competence and adequacy of staff
- perform safety reviews of both plant modifications and organisational changes
- submit the reviewed modifications and changes to SKI, which can add further requirements
- perform systematic analysis of events.

2.6.2 Methods and approaches

Considerable progress has been made in the past few years, learning from experience in applying process based oriented tools and methods for regulatory supervision of major plant modifications and of plant organisational improvement programs (SKI Inspection Guidebook-Maintenance, 1994; Quality Systems Inspections Handbook, 1993; Dahlgren & Olson, 1994; Olson & Thurber, 1991).
The guidebook developed by SKI for assessing Maintenance Program Effectiveness provides one approach in assessing aspects of Management Functions and Oversight. The assessment of the maintenance program status requires:

- identifying the essential elements of effective maintenance programs. The elements are organised into the following five resource functions; people, tools, material, information and co-ordination
- viewing the maintenance program as a system of interrelated elements and activities with linkages within teams, within each element and function, and between maintenance and other departments
- evaluating the goals and the plans to achieve the goals within each element.

The guidebook contains a list of general questions and related information under each heading in order to assist the inspector in preparing the inspection. On each page there is an improvement figure to remind him of gathering information on the:

- past: what has been the performance in the past
- present: what is the current performance situation
- future: what are the performance goals and what are the plans to reach these goals?

The guidebook is also used by utilities in self-assessments in order to develop baseline documents.

The learning of an organisation is assessed by SKI by addressing the following dimensions (Dahlgren & Ohlson, 1994; Olson & Thurber, 1991):

- problem recognition: the ability to recognise that performance problems exist
- problem diagnosis: the ability to accurately characterise the nature of the problem
- solution formulation: the ability to come up with viable solutions

- solution implementation: the ability to put solutions into place
- assessment and feedback: the ability to monitor the effects of the solution and to make adjustments as required.

Strengths and weaknesses are explored in all dimensions and in their supporting organisational aspects such as goal setting, communications, co-ordination, resource allocation etc.

The framework has been used in both normal and topical inspections of for example management and practise of training and evaluation, in-service inspections, plant experience feedback of events relating to the interaction of man-technology-organisation as well as management and practise in handling plant modifications.

Triggered by several indicators of deficiencies in safety management at one site SKI conducted an extensive inspection project focusing on a number of areas of importance to safety. This inspection project covered the areas mentioned above and also included organisation and safety culture, internal safety assessment, feedback of operating experience, management of plant human factors work, management training, and control room work.

The inspections focused both on the formal system and actual practise. Instructions and other documents were reviewed and structured interviews were performed on-site with management and staff. Mixed teams of inspectors with background in plant operations and expert reviewers including experts on the interaction man-technology-organisation carried out the inspections. Feedback of SKI findings, conclusions and recommendations were given to management and staff, in meetings on-site, in order to create a common understanding of organisational processes and any deficiencies with regard to safety and quality, stressing the licensee ownership of safety work.

Based on these experiences SKI has decided to submit one site a year to a similar in-depth inspection effort, even if there are no indicators of deteriorating safety performance.

2.7 Switzerland

2.7.1 Context and framework

Switzerland operates two BWRs and three PWRs on four sites. Inspectors of the Swiss Federal Nuclear Safety Inspectorate (HSK) have regular contacts with the plants for inspections and discussions on special issues and the safety evaluation of the plants.

The Swiss Federal Nuclear Safety Inspectorate (HSK) has issued regulations on the Organisation of NPPs and on the Training of licensed NPP personnel. They describe the basic requirements on the organisation of Swiss NPPs but they don’t provide a structured method nor clear criteria for the evaluation of organisations. In the case of periodic safety reviews and in the case of the detection of organisational weaknesses in inspections and especially in the event analysis the HSK does a deeper investigation of organisational issues by doing document reviews, additional inspections including interviews of people at the plant.

At the time there is no formal system in force for the observation of organisational factors.

In two Swiss NPPs OSART Missions have been conducted in 1994 and 1995 as well as the corresponding follow-up missions. The plants have taken the OSART results very seriously and special programmes have been initiated in order to improve organisational and safety performance. In 1999 and 2000 the two remaining plants will undergo a OSART review as well.

2.7.2 Methods and approaches

After the Three Miles Islands (TMI) accident the Swiss Federal Council asked the HSK to evaluate if an accident like TMI would be possible to occur in Switzerland. Besides technical investigations, the HSK initiated 1981 an in-depth evaluation of organisational factors in the Swiss NPPs, based on an «organisational climate» model. Members from nuclear power plants, delegates of the Swiss Federal Nuclear Safety Inspectorate (HSK) and a psychological institute developed questionnaires and interviews for the overall assessment of social climate aspects. The result of this investigation was rather positive and there was no need for a follow up.

Nowadays deeper investigations on organisational issues are done in the case when events or inspections reveal organisational deficiencies. In these cases a group of HSK inspectors go to the plants for interviews, document reviews and further inspections. The findings are discussed with the plant managers and depending on the severity of the issue, the utility is required to propose solutions for the resolution of the problem. Clear deadlines are set and surveyed for the proposal as well as for the implementation of the solution.

Recently a project has been started at HSK with the aim to involve Technical Inspectors (inspectors on technical issues, non human factors specialists) in the observation of organisational and human factors issues during their regular inspections. Important factors will be identified and criteria developed in order to detect early signs of deteriorating safety performance. It is planned to gather information corresponding to these criteria with the help of observations obtained during technical inspections, walk through and meetings. Human Factors experts will either be part of the inspection team or will interview the inspectors after they have finished their inspections. All findings will be collected by the Human Factors Department of HSK. Periodically this department will discuss the findings with the management of each plant. This will help the plants management to have an alternative view additionally to their own assessment.

In the field of safety culture a research project financed by the regulatory body (HSK). It will be used for analysing minor incidents that could have resulted in more severe accidents. Based on document reviews and interviews scenarios are created, where people will be asked what they would have done in a given situation. Furthermore managers will be asked, how their people would have reacted to certain incidents. This method will conducted as self-assessments in the plants. One key factor is confidentiality and anonymity. Such an method will fail if individuals believe that they will be identified.

2.8 United Kingdom

2.8.1 Context and framework

The legislative framework within the UK requires that no one should use a site for the construction or operation of a nuclear installation without a licence from the UK's Health and Safety Executive. The Nuclear Safety Directorate is that part of the Health and Safety Executive responsible for ensuring that nuclear power related activities are carried out in a safe manner. NSD makes day to day judgements about the organisational aspects of licensees through the routine regulatory site activities of its inspectors. There are also occasions when the corporate management system is examined for its adequacy in ensuring nuclear safety.

Applicants for nuclear site licenses are required to demonstrate to the satisfaction of NSD that they are capable of discharging the duties placed upon them under the UK's Health and Safety at Work Act and the Nuclear Installations Act in a proper manner. Similarly, existing licensees need to be capable of demonstrating compliance with conditions attached to their nuclear site licences. This is usually done through a combination of the administrative arrangements which outline the management organisation, the systems used to manage safety on the site, the written safety case for the plant (or plants) which describes the design and the expected behaviour of plant both when operating and in fault conditions.

The current arrangements for granting nuclear site licences are described in a UK publication 'Nuclear Site Licences - Notes for Applicants.' In this document is a request for a 'Management Prospectus'. The purpose of the prospectus is to demonstrate that the user of an installation has an adequate management system to discharge the obligations connected with being the holder of a licence.

The thrust of the UK's Health and Safety at Work Act, the Management of Health and Safety at Work regulations and the licensing requirements of the Nuclear Installations Act is that the operator should manage safety. Additionally, the scope of the NSD standard licence conditions, the HSE guidance on licence conditions and the HSE publication, Safety Assessment Principles for nuclear plants cover important aspects of managing safety. The non prescriptive wording in the 35 conditions attached to a site licence is intended to encourage licensees to adopt a proactive approach to the matter of developing arrangements that suit their individual circumstances and risks while demonstrating that safety is managed effectively.

2.8.2 Methods and approaches

The Health and Safety Executive has developed a general systems approach which is described in its document "Successful Health and Safety Management". NSD has taken this document and produced a nuclear version entitled 'Managing for Safety at Nuclear Installations'. This is used by inspectors to audit organisations. Inspections are based on documentation reviews, interviews and walk throughs. This approach is also the reference for helping utilities to build their organisation systems. Every function in an organisation (e.g. Training or Communication) can be assessed as a dynamic management process. The starting point is to first look at what is formalised in the process.

There are six major steps included in the process:

Policy: Goals have to be set by the management. The characteristics of an effective health and safety policy are that it:

- supports human resources development
- minimises the financial losses which arise from avoidable unplanned events,
- recognises that accidents, ill health and incidents result from failings in management control and are not just the fault individual employees,
- recognises that the development of a culture supportive of health and safety is necessary to achieve adequate control over risk,
- ensures a systematic approach to the identification of risks and the allocation of resources to control them,
- supports quality initiatives aimed at continuous improvement

Organising for health and safety involves establishing responsibilities and relationships. The structures and processes in organisations have to establish and maintain management control within an organisation though:

- managers who lead by example,
- a clear allocation of responsibilities for policy formulation and development, for planning and reviewing health and safety activities and for implementation of plans and for reporting on performance,
- allocation of people with necessary authority and competence who are given the time and resources to carry out their duties effectively,
- ensuring that individual are accountable for their responsibilities and are motivated by a system of target setting and positive reinforcement,
- provision of adequate supervision, instruction, and guidance,
- payment and reward systems which avoid conflict between achieving output targets and health and safety requirements,
- promote co-operation between individuals, safety representatives and groups so that health and safety becomes a co-operative effort,
- involving personnel in policy formulation and development and in planning, implementing, measuring, auditing and reviewing performance,
- making arrangements for involvement at the operational level to supplement more formal participative arrangements,
- ensure effective communication by means of visible behaviour, written material and face to face communication,
- secure the competence of employees.(through recruitment, selection, placement, transfer and training and the provision of adequate specialist advice),

Planning and implementing: There is a need to establish, operate and maintain systems which:

- identify objectives and targets,
- set performance standards for management actions (control, competence, communication and co-operation),
- eliminate the risks by substitution of safer premises, plant and substance and where this is not reasonably practicable, control the risks by physical safeguards which minimise the need for employees to follow detailed systems of work or to use protective equipment,
- establish priorities for the provision and maintenance of control measures by the use of risk assessment techniques giving priority
- to high risk areas or adopting temporary control measures to minimise risk,
- set performance standards for the control of risks both to employees and to others who may be affected by the organisation activities, products and services,
- ensure the adequate documentation of all performance standards.

Measuring performance: There is a need to establish active monitoring, reactive monitoring and reporting and response systems, which:

- measure the achievement of objectives and specified standards and reflect risk control priorities by concentrating on high risk activities,
- collect and analyse information suggesting failures in health and safety performance,

- ensure that information from active and reactive monitoring is evaluated by competent people to identify risk situations and ensure that appropriate remedial action is taken,
- investigate to ensure that;
- reports arise from active and reactive monitoring systems, the identification of immediate and underlying causes of events,
- the referral of information to the level of management with authority to initiate the necessary remedial action, including organisational and policy change
- the adequate analysis of all collected data.

Review performance and audit systems in order to ensure that:

- information is obtained by the use of in-house auditing systems or external auditors on the validity and reliability of the management planning and control systems,
- appropriate remedial action is taken and progress in implementing remedial action is followed through according the plan,
- the overall effectiveness of policy implementation is assessed internally in particular on;
- assessment on degree of compliance with performance standard,
- identification of areas where standards are absent or inadequate assessment of the achievement of specific objectives,
- accident and incident data with analyses of immediate and underlying causes, trends and common features.

The model is used by looking at vertical and horizontal slices through an organisation. For example, in assessing the managerial approach to training, staff are questioned about the training policy, the responsibilities for training, the competence, co-ordination, communication and control aspects, who plans the training, who reviews it and who carries out internal and external audits of the process. In this way, gaps in the dynamic process can be identified.

One area which has become more important in recent years is the management of change. Privatisation and mergers within the nuclear industry have meant that the scale and rate of change is greater than ever before. Change is always occurring, but to ensure that safety is not degraded, the Nuclear Safety Directorate has produced internal guidance on assessing the implications of change and carried out a number of management of change inspections. Features of such a process are; what needs to occur before change can take place, e.g. reduced workload, retraining; what indicators are to be used to monitor the change and; what contingency plans are in place should the anticipated activities not occur.

Increased contractorisation has also led to a need to assess how licensees are using contractors. Again, internal guidance has been produced and licensees have to demonstrate to NSD that whilst they may employ contractors, they have effective control and supervision over their activities and corporate expertise and memory is not lost to the contracting company.

The regulatory approach is therefore to assess licensees human factors, quality assurance and management of safety activities in order to ensure that robust, transparent and auditable systems are in place. Checks are made through routine site inspection activities coupled with targeted inspections at both sites and corporate facilities. NSD human factors and management of safety specialists are members of these teams. They also review the management prospectuses for new licensees or when an existing licensee is considering changing its organisational structure.

2.9 United States

2.9.1 Context and Framework

The NRC licenses the construction and operation of nuclear power plants; develops, implements, and enforces the rules and regulations that govern nuclear activities; inspects facilities to ensure compliance with regulations; and conducts research to support its programs. The NRC maintains at least two resident inspectors at every operating nuclear reactor site and supplements inspection activities with staff from any of its four regions and from NRC headquarters.

2.9.2 Methods and approaches: Organisational Performance Assessment

The NRC monitors and assesses the performance of power plant licensees to verify that plants are operating safely. The NRC uses various methods to do this including: inspections at licensee facilities to gain independent assurance that licensees are operating safely and licensees report to NRC on their plant's conditions and events. NRC's on-site inspectors prepare reports on a plant's performance covering all aspects of nuclear plant operations. NRC prepares a summary of plant performance approximately every twelve months and uses this guide for determining the plant's need for additional inspection attention. NRC also developed eight performance indicators for monitoring the safety performance of licensees and to improve its ability to predict declining performance.

NRC conducts performance-based inspections on facility operation and design and on the basis of inspection results, draws conclusions about organisational performance. The current NRC inspection program assesses compliance with existing regulations and develops performance insights by observing the conduct of operations, material condition of the plant, performance of licensee personnel, quality of engineering work, and the licensee's performance in problem identification and resolution. The NRC inspection program also involves evaluation of operational events to identify root causes such as human error, design deficiencies, and weak administrative controls. The NRC then assesses overall plant performance and infers licensee organisational management performance based on a comprehensive review of inspection findings, licensee amendments, event reports, enforcement history, and performance indicators.

NRC also conducts limited scope evaluations of organisational performance in response to specific operational events or adverse human or program performance trends. When evaluations in this area have been conducted in response to specific events, they have typically been conducted as elements of Special Inspection Teams, Augmented Inspection Teams, and Incident Investigation Teams. If there is evidence of declining performance, other types of inspections are conducted. NRC may require that the licensee conduct a self-assessment (may be done in-house or by a consultant). NRC staff will then review the self-assessment and the recommended corrective actions for addressing the identified problems, to determine its adequacy. Hence, NRC's references to organisational performance are usually made retrospectively.

When the NRC evaluates aspects of organisational performance whether for event follow-up or continuing declining performance, it may use one or more of several assessment methods which include: various Inspection Procedures, e.g., IP40500 "Effectiveness of Licensee Controls in Identifying, Resolving, and Preventing Problems"; guidelines, e.g., NUREG-1545 "Evaluation Criteria for Communications-Related Corrective Action Plans"; document reviews including Licensee Event Reports (LERs) and Inspection Reports and use of the Human Factors Information System (HFIS) an automated database of human factors information for each nuclear power plant; direct observations; interview protocols; the Human Performance Inspection Process (HPIP), an event follow-up process consisting of five modules:

Procedures, Training, Organisation/Management, Communications, Human Engineering, Supervision (see further description under Research); MORT. Depending on the scope and purpose of the inspection, some of the organisational factors that are evaluated may include: goal and objective setting; roles, responsibilities and accountabilities; communications and coordination; decision-making and problem-solving; management support; human resources programs; work processes; procedures program; planning and scheduling; self-assessment and problem identification; staffing and workload; working hours and overtime; training and development; human-system interface issues; corrective action and improvement programs; organisational learning; safety culture.

Another aspect of organisational performance is the Safety Conscious Work Environment (SCWE). The SCWE is an aspect of the safety culture that addresses the trust and confidence of nuclear power plant employees in its management's ability to resolve employee concerns without fear of discrimination. Review of a licensee's SCWE is done on a case-by-case basis, through the review of allegations of chilling effect; special task forces; inspections of licensees' Employee Concerns (EC) programs on an as-needed basis; or by ordering a licensee to perform a survey of its Safety Conscious Work Environment (SCWE).

Lastly, NRC's Inspection Manual includes a number of Inspection Procedures which, when conducted, can provide information from which to infer organisational performance at the licensee's facility. These include Training and Qualification Effectiveness, Emergency Operating Procedures, Feedback of Operational Experience Information at Operating Plants, Fitness for Duty, Management Effectiveness-Security Program, Plant Operations, Allegations Review, Resolution of Employee Concerns, Licensee Self-Assessment Related to Team Inspections, Organisation, Licensee Management of QA Activities, Prompt Onsite Response to Events at Operating Power Reactors, Corrective Action, Operational Safety Team Inspections, Augmented Inspection Team Implementing Procedure.

3. RESEARCH PROGRAMS REPRESENTED AT THE WORKSHOP

Type of research

It is useful to distinguish two categories of research represented at the workshop. In the first category, that we will call «**University-based research»,** the research agenda is partially influenced by the sponsors. Results are published in academic journals and contribute to the research field (e.g., social psychology, sociology of work, organisation theory, organisation behaviour and so on...). The direct application of the results is often not the primary objective but eventually may lead to this. The following programs belong in this category:

- Program from the University of Bern (Switzerland): A Situational Approach to Assess Safety Culture
- Program from the Swiss Federal Institute of Technology (Switzerland): A Sociotechnical Model of Safety Culture: Total Safety Management
- Program from the University of Technology of Compiègne (France): A Sociological approach to study Organisational Reliability

In the second category, called «Public and Private Laboratory or contractor based research», the links between the sponsors (Utilities, regulatory bodies, government agencies...) and the research team are much closer. The research plan and the tasks are agreed upon and must meet the sponsors' specific needs. Belonging to the second category are the following projects:

- The CIEMAT project (Spain): Developing methods and models to evaluate the impact of organisational factors on Nuclear Power Plant safety
- The VTT Automation project (Finland): Evaluating Organisational Reliability through Process Modelling
- The Brookhaven National Laboratory project (USA): Organisational Processes and Nuclear Power Plant Safety
- The Obninsk Scientific Centre «Prognoz» (Russia): A Longitude Verification of the Organisational Factors's Influence on Nuclear Power Plants' Reliability
- The OECD Halden Reactor Project (Norway): The integration of Organisational Factors in PRA/HRA
- The Korea Institute of Nuclear Safety Project: Organisational Factors, identification and assessment

- *NRC: Organisational Factors in Performance Reliability*
  - NRC’s Organisational Performance Research
  - NRC: Evaluation Criteria for Communications-Related Corrective Action Plans

- Root cause Investigation Improvements
- Human Reliability Analysis
- Management and Organisational Factors in PRA

Category 1 - University research based

Program from the University of Bern (Switzerland): A Situational Approach to Assess Safety Culture

Main researchers:	Norbert Semmer, and Alex Regenass
Sponsors:	Program sponsored by HSK (Hauptabteilung für die Sicherheit der Kernanlagen)
Objectives:	Developing a situational method for the management of Swiss Nuclear Power Plants in order to assess themselves the safety culture of their plant.
Publication:	Semmer and Regenass (1998)

The research background:

Semmer and Regenass argue that many approaches to the study of *safety culture* focus on values and social norms and their underlying assumptions. Most existing research tools and instruments are designed to collect data on norms and assumptions. However social science research has long demonstrated that the correlation between general preferences and specific behaviour is rather modest. In fact way too thin to actually predict the behaviour that will effectively be chosen by the actor. As the researchers explain: «Responses to general questions do not guarantee that the aspects salient in the measurement situation are the same ones that are salient in a real-life situation. Moreover, it has been shown that actors do not behave according to one single norm, they are rather confronted to different and often competing norms. Which norm will dominate cannot be determined from understanding the norms, but rather by careful consideration of situational aspects».

The research apparatus:

The Situational Approach suggests that the emphasis should be put on collecting data on actual practices, real dilemmas and decisions (what is also called «theories in use») rather than on social norms.

Acknowledging that values and assumptions are expressed in situations, Semmer and Regenass propose a situational approach, in which subjects are not directly questioned about values and norms, but are confronted with dilemma that stems from conflicting social norms and various costs and benefits associated with different types of behaviour. The subjects are asked what they would do in such a situation, what they think others would do, what reactions they would expect their behaviour to elicit from others, and so forth.

Interviews are conducted with various experienced people at the Plant, who are deliberately asked to tell what they would have done in front of various scenarios (like recurrent minor incidents or day-to-day difficulties). They are asked to describe what they would have done, how they would think about it, what their colleagues were thinking at the time; if there was a consensus or rather conflicting views on the issue, etc.

This kind of information is crucial for the researchers because it helps them to understand the conditions under which certain choices and alternatives are considered, rejected and finally adopted. It is only in a second stage that the researchers will link the practices and observed behaviours with social norms.

The research status:

The research is still in development, especially the last part of the project which will attempt to link observed practices and social norms.

Program from the Swiss Federal Institute of Technology (Switzerland): A Socio-technical Model of Safety Culture: Total Safety Management

Main researchers:	Gudela Grote and Cuno Künzler, from the Work and Organisational Psychology Unit, Swiss Federal Institute of Technology (ETH)
Sponsors:	various industries
Objectives:	This research is aiming at developing a method devoted to assessing *safety culture* as well as the overall organisational makeup of high risk organisations. The original research was based on the study of four chemical companies and one transportation company and was extended by studying petrochemical plants in connections with insurance audits.
Publication:	Grote and Künzler (1996 and 1997)

The research background:

The researchers are combining a theoretical framework - the *socio-technical systems approach* founded by Emery and Trist (Emery, 1959) with an audit methodology. It is the researchers' claim that mixing the two can be fruitful to assess safety culture but more importantly the organisation as a whole. It is Grote and Künzler's opinion that models of safety culture - that have flourished after INSAG 4 - suffer from a lack of integration into general models of organisation and of organisational culture. In addition the connection between safety-related characteristics of a system and more general characteristics like job and organisational design and the use of technology, is missing. It gives the impression that safety can be looked upon and promoted as something detached from the make-up of the sociotechnical system as a whole.

For Grote and Künzler, the socio-technical approach describes work systems as having a technical and a social subsystem which together determine how well the primary task of a work system can be accomplished. In this perspective, maximum effectiveness can be achieved, only if the two sub-systems are jointly optimised. Both researchers argue that on at least two levels the Socio-technical approach can be linked to safety: a) The definition of the primary task; b) the degree of self-regulation of sub-units in the system. From this follows: a) the definition of the primary task should include safety, to foster - in analogy to the Total Quality Management approach - a Total Safety Management; b) A high degree of self-regulation of work teams is beneficial to safety, because it fosters flexibility, initiative and ownership, which are all crucial qualities to adequately deal with problems or incidents.

Therefore, a model of safety culture should be incorporated into a more general model of organisational culture, emphasising complex interactions between an organisation’s material and immaterial reality.

Secondly, characteristics of the work system not directly related to safety should be included, especially characteristics of job and organisational design influencing the degree of self-regulation on the shop floor.

Research apparatus:

Field-work has been performed in 4 chemical plants and one transportation company, with the use of mixed methods and tools (observations, interviews, questionnaires). Two main results emerge:

- The integration of safety into day-to-day operations is easier in organisations whose primary task is defined in terms of quantity, quality *and* safety of production, as opposed to organisations whose primary task is only defined in terms of quantity and quality.
- There is evidence that safety awareness, organisational and technical design are positively correlated.

Research status:

This group is now involved into the creation of a more specific list of indicators, which is the basis for the development of a questionnaire that in conjunction with interviews and work place observations can be used in safety culture audits.

Currently, the group is looking in depth at incident-inducing as well as recovery factors in commercial aviation in order to test basic assumptions of the Total Safety Management model in another work environment.

Program from the University of Technology of Compiègne (France): A Sociological approach to study Organisational Reliability

Main researcher:	Mathilde Bourrier, Department of technology and human sciences
Sponsors:	Program sponsored by the C.N.R.S. (Centre National de la Recherche Scientifique) and by I.P.S.N. (Institut de Protection et de Sûreté Nucléaire).
Objectives:	This research is an attempt to contribute to the study of Organisational Reliability in High-Risks Industries through a sociological analysis, using organisation theory and anthropological methods. The goal is to identify crucial social nodes, supporting and fostering Organisational Reliability in a given organisation. Using the concept of «Strategical compromises», that have proven to be at the core of Organisational Reliability, the research primary task is to determine the conditions under which these compromises are emerging in order to assess their strengths and weaknesses, their costs and benefits. This will give access to a deeper understanding of dysfunctional patterns in organisations for early detection.
Publication:	Bourrier (1994, 1996a&b, 1998 and in press)

The research background:

Too often, organisational analyses are carried out only after a catastrophe has occurred. While very interesting, this perspective has serious limitations: it is always easier to explain and reconstruct events after they have taken place. It is more essential to understand the mechanisms of «normal» functioning, because having a correct perception of their «normal» operation can help to prevent future dysfunctions and possible errors. In this way, it should be possible to predict in what areas failures are more likely to occur. To do so, organisational reliability should be researched through the study of social interactions and professional relations. Bourrier's claim is that Organisational Reliability is highly dependent upon the «quality» and the «nature» of social relations, which are driven in turn by self-interest and «deal», and hence by power and strategies (which could introduce dissent, compartmentalisation, power struggles and goals displacement, poorly reliable features of most organisational life). This research suggests that Organisational reliability should be investigated and seen as a property of the social systems embedded in «reliability-seeking organisations». The social construction of organisational reliability can best be analysed through a systemic analysis thus helping to focus on systemic effects.

Research apparatus:

This research began in 1991 based on a study of the organisation of maintenance and outage activities in four nuclear power plants, 2 in France and 2 in the U.S. Three to Five months were spent at each site collecting information, observing job sites progression and conducting a total of 300 interviews with plant personnel from all the categories involved in scheduled outages.

The «Strategical Analysis Method», which focuses on the collection and the analysis of work practices rather than on actors opinions on their work, was used (For a description of this method, see Friedberg, 1972). This approach allows to combine anthropological methodology (study of situated practices) and classic systemic analysis of work.

Research status:

Under development, new field-work is programmed, focusing on other parts of the Nuclear socio-technical system (including regulators). Comparisons with other high-reliability organisations (airlines) is also under discussion.

Category 2 - Public and Private Laboratories research based

The CIEMAT project (Spain): Developing methods and models to evaluate the impact of organisational factors on Nuclear Power Plant safety

Main Researchers:	Rosario Solá, Celina Vaquero, Isabel Garcés
Sponsors:	This project is carried out by CIEMAT in collaboration with Spanish universities and sponsored by the Spanish Nuclear Regulatory Body (CSN, Consejo de Seguridad Nuclear) and the Spanish utilities (UNESA). Some of the tasks included in this project will be performed also in co-operation with other international institutions.
Objectives:	Development of a five-years R&D project, entitled «Development of methods for evaluating and modelling the impact of organisational factors on nuclear power plants safety».
Publication:	Solá, Vaquero and Garcés (1998)

Research background:

The CIEMAT project started off with a literature review[1] of the most important research lines and projects focusing on the impact of organisational and management aspects in the achievement of safe and reliable operation (see ref. 5 and bibliography). It is not our intend here to summarise the report written by CIEMAT but rather to mention its existence to members of the community. One of its main contributions is that it identifies clearly the diversity of responses given by different countries and institutions to a common and still obscure problem. Following this review, the researchers developed a five years project, laid down below.

The Five Years Project:

The main goal of the proposed R&D project is to increase the knowledge related to the way Nuclear Power Plants organise and manage their activities to enhance safety. Three sub-goals will be pursued:

- Development of preventive methodologies,
- Development of corrective methodologies and
- Development of models to include organisational factors into Probability Safety Assessments.

Associated with these three sub-goals, the researchers have laid out a five tasks planning. Part of these tasks will be performed in close co-operation with other institutions allowing for methodologies transfer.

Task 1 - The «Concerted Action»:

> Developing and fostering international co-operation on this subject. The general aim of this task is to participate in a European forum, whose goal is to develop exchanges on the impact of organisation on NPPs safety and subsequently to draft a research proposal for the European Community V Framework Program.
>
> Members of the «Concerted Action» forum are the following: Technology University of Berlin (Germany); HSE (Great-Britain); HSK (Switzerland), IPSN (France); Vattenfall Energisystem (Sweden); VTT Automation (Finland).

Task 2 - «Development of organisational models, organisational factors identification and development of evaluation methods”.

> Its goal is the development of an organisational model which would allow the identification of organisational factors with impact on safety and lately, the development of preventive methodologies to assess the organisational performance.
>
> This task will be conducted in co-operation with AECB (Canada).

Task 3 - «Analysis of the relationship between organisation and safety in refuelling outages”.

> The goal is to develop a preventive methodology devoted to the understanding of the organisational performance during refuelling outages.
>
> This task will be achieved in co-operation with IPSN (France).

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1 The results of the literature review have been collected in a database.

Task 4 - «Incidents and operating experience analysis methodologies”. The objective of this task is to get a corrective tool which allow organisational problems identification and correction adapted to the Spanish environment.

Task 5 - «Development of models for the inclusion of organisational factors in Probabilistic Safety Analysis, PSAs”.

Finally, this task will enable the researchers to develop models that incorporate organisational factors into Probability Safety Analysis. The task would be framed in the activities performed in the International Coordinated Program in PRA promoted by NRC, COOPRA.

Research Status:

Currently the R&D Five Years Project, included the «Concerted Action» task has started.

The VTT Automation project (Finland): Evaluating Organisational Reliability through Process Modelling

Main Researchers:	Björn Wahlström and Jari Kettunen, the «High Reliability Organizations Team» of VTT Automation.
Sponsors:	Mainly utilities and the Finnish Radiation and Nuclear Safety Authority (STUK).
Objectives:	To analyse and develop organisational practices in the field of nuclear power and other high-risk industries.
Publications:	Wahlström, Laakso and Tamminen (1987); Wahlström (1992, 1994 and 1996).

Research background:

It is the researchers opinion that despite the fact that it is now widely acknowledged that organisational factors have a significant impact on nuclear safety, a general framework and methods for a comprehensive assessment of organisational factors and management issues are still missing. VTT’s approach is based on the application of systems engineering and behavioural sciences.

Research activities:

The research performed within the «High Reliability Organizations Team» at VTT Automation can be distinguished in the following main activities:

- Man-Machine Psychology
- Probabilistic Safety Assessment and Human Reliability Analysis
- Organisation and Management Studies

In the field of organisation and management studies the main objectives are:

- To identify the most important factors influencing organisational safety, reliability and efficiency
- To create feasible methods for modelling and evaluating organisational practices
- To establish indicators of organisational excellence and safety culture
- To develop practicable and reliable tools for self-assessment

In addition, VTT Automation tries to provide its customers with useful propositions for further actions whenever possible or adequate.

The main phases for evaluating organisational practices:

- Get acquainted with the organisation and the selected work process using available documentation.
- Create a preliminary model of the selected work process and evaluate it against generally applied standards and principles.
- Select an actual case that exemplifies the process under investigation and evaluate it against the process model.
- Interview people who are involved in the selected work process and who have participated in the selected case.
- Refine the process model and assess the selected work process on grounds of the new context specific information.

VTT Automation has conducted two international benchmarking exercises to assess plant modification and safety inspection processes in some Finnish, Swedish and British nuclear power plants. Experience from the studies demonstrates that the modelling approach facilitates the exchange of information by providing a common framework for business and work process description and analysis. These models have also proved to be efficient tools for building up a shared understanding of the process under investigation.

When evaluating organisational practices in some foreign utility it is very important to have a general understanding of the specific nuclear legislation and regulatory approach in that country. It is also advisable to pay attention to the prevailing economic situation and its implications for the nuclear industry.

The Brookhaven National Laboratory project : Organisational Processes and Nuclear Power Plant Safety

Main Researcher:	Sonja Haber
Sponsors:	Regulatory bodies including USNRC, and AECB (Canada).
Objectives:	After having identified the categories of organisational factors relating to Nuclear Power Plants' safety, the research in a second stage has been focusing on the design and the validation of methods for measuring these organisational factors. The third phase, currently under development, is an attempt to integrate those dimensions into

Probability Risk Assessment or other safety assessment. All these tools are designed mainly for regulators, and constitutes a preventive methodology, that can be used both in evaluations and licensing processes[2].

Publication: Haber, O'Brien, Metlay and Crouch (1991), Jabobs and Haber (1994)

Research Background:

The researchers' starting point clearly identified that: «..a complete understanding of the human factors issues affecting performance has to include the broader areas concerning the organisation itself, the atmosphere in which the individuals work, and the hardware and software with which they must interact», (Jabobs & Haber, 1994, p. 76).

Originally, sponsored by the NRC, the project started off with a primary task devoted to finding a consensus on the important organisational factors leading to safe power plant performance. Out of this broad literature review, Haber identified 20 factors or dimensions, directly in relation to safety (Haber, 1994; Haber et al, 1991).

The Brookhaven work used Mintzberg's Model called the «Machine Bureaucracy» as a framework capable of capturing Nuclear Power Plants organisational specifics. In its Model, Mintzberg distinguishes five functional elements within the organisation: the operating Core, the strategic Apex, the Middle Line, the Techno-structure and the Support staff. According to this model, nuclear power plants organisations have been analysed through the prism of 5 categories, split in 20 dimensions, all in conjunction with safety.

We will briefly mention these categories and dimensions (see table below). They constitute one of the first systematic effort to direct attention towards organisational areas, especially crucial to safety. The systematic use of these dimensions, supposedly important for the safety of all nuclear power plants, allow for comparisons between plants, and countries. However, the recent work done by Haber at the request of AECB in Canada showed that Mintzerg's model did not adequately describe the influences of corporate level and dynamic external processes on Canadian NPPs. Some adjustments had to be made which produced an hybrid model called CAMM (Canadian Adaptive Machine Model).

In a second phase of the project, several methodologies (Surveys, Behavioural Checklist, Structured interview, Behaviourally Anchored Rating Scale) have been used in order to evaluate each organisational dimension with plant personnel. By themselves, the organisational factors can help in locating areas within an organisation where «weak links» may exist.

2 For a good description of this research program see also Sola, Vaquero and Garcès (1998, pp. 2-10)

CATEGORIES	DIMENSIONS
Administrative Knowledge	Coordination of Work Formalization Organisational knowledge Role and responsibilities
Communications	External communications Interdepartmental communications Intradepartmental communications
Culture	Organisational culture Ownership Safety Culture Time urgency
Decision Making	Centralisation Goal prioritisation Organisational Learning Problem identification Resource allocation
Human Resource Allocation	Performance evaluation Personnel selection Technical Knowledge Training

Tab. 1: Categories and Dimensions used in the Analysis of Nuclear Power Plant's Organisations.

Research status

Currently, these 20 dimensions are incorporated into Risk Assessment through the analysis of work processes. This phase is an extend of the Brookhaven National Laboratory work. It is mainly developed by Davoudian, Wu and Apostolakis, designers of the WPAM [Work Process Analysis Model] model (Davoudian, Wu & Apostoloakis, 1994a&b). The main goal of this project is to propose a **structured model** that can go beyond qualitative analyses. However, it has to be said that WPAM could only be developed because qualitative work had been done before. Along with Cornell's SAM [Systems, Actions, Management] model (Paté-Cornell & Fischbeck, 1993; Paté-Cornell & Murphy, 1996), and Embrey's SLIM-MAUD [Success Likelihood Index Methodology Using Multi Attribute Utility Decomposition] model (Embrey, 1992), WPAM I and II are first attempts to take into account in PRA the influence of organisational factors and maybe more importantly on common-cause effect of organisational factors.

NRC's Organisational Performance Research

NRC: Organisational Factors in Performance Reliability

Research Entity:	Brookhaven National Laboratory (BNL)
Sponsor:	USNRC
Objective:	The BNL project for the NRC is addressed under BNL research elsewhere in this report.
Publication:	NUREG/CR-5538/BNL-NUREG-52301 „Influence of Organisational Factors in Performance Reliability," 1991.
Research Status:	Completed.

NRC: Evaluation Criteria for Communications-Related Corrective Action Plans

Research Entity:	USNRC
Sponsor:	USNRC
Objective:	To provide guidance and criteria for NRC personnel to use in evaluating corrective action plans for nuclear power plant communications.
Publication:	NUREG-1545 „Evaluation Criteria for Communications-Related Corrective Action Plans," February 1997.

Research Background:

This document was developed by NRC staff based on previous research and is used to evaluate the „Communications" organisational factor. This document provides guidance and criteria for NRC staff to use in evaluating corrective action plans for nuclear power plant communications. It consists of evaluation criteria elements, interview protocols, and a communications observation protocol.

Research Status: Completed

NRC: Root Cause Investigation Improvements

Research Entity:	Performance, Safety and Health Associates (PSHA)
Sponsor:	USNRC
Objective:	To improve the HPIP to be more useful to NRC's inspection staff in their review of human performance issues.
Publication:	The Human Performance Investigation Process (HPIP), NUREG/CR-5455, System Improvements, Inc. and Concord Associates, Inc., 1993. NUREG/CR of revised HPIP to be published.

Research Background:

The HPIP was intended to be used by NRC inspection staff who do not have a background in human factors to perform field investigations of the root cause(s) of human performance problems in events. HPIP consists of five modules: Procedures, Training, Management and Organisation, Human Engineering, and Supervision and includes techniques such as events and causal factors charting, barrier analysis, and change analysis. Several years of experience in applying HPIP demonstrated that the process has provided important insights regarding human performance contributions to events, however, it also showed that modifications could improve HPIP’s usability. The tasks completed include a literature review of root cause analysis tools and techniques, a survey of NRC inspection staff to identify the strengths and weaknesses in HPIP, and an on-site (at a nuclear power plant) evaluation of HPIP.

Research Status:

Based on the results of the above tasks, one of the modules (Communications) in HPIP is being modified. This revised module will be pilot-tested and revised. An approach for enhancing the other HPIP modules will be described.

NRC: Human Reliability Analysis

Research Entity:	Brookhaven National Laboratory, Wreath Wood Group, Buttonwood Consulting, Science Applications International Corporation, Sandia National Laboratory, NUS-Haliburton, John Wreathall & Co.
Sponsor:	USNRC
Objective:	A Technique for Human Error Analysis (ATHEANA), NUREG/CR-6350,BNL-NUREG-52467, was published in May 1996. This work was sponsored by the NRC and conducted by a multi-disciplinary team of contractors. ATHEANA is a second generation HRA method which was developed to provide a structured approach for analysing operating experience and understanding nuclear power plant safety, human error, and the underlying factors that affect them.
Publications:	NUREG/CR-6350/BNL-NUREG-52467 „A Technique of Human Error Analysis (ATHEANA), May, 1996; NUREG-1624 Draft for Comment, Technical Basis and Implementation Guidelines for a Technique for Human Event Analysis (ATHEANA), May 1998

Research Background:

ATHEANA is a second generation HRA method based on a multidisciplinary framework that considers both the human-centered factors (i.e., performance shaping factors such as human-machine interface design, procedures content and format, and training) and the conditions of the plant that gave rise to the need for actions and create the operational causes for human-system interactions (e.g., misleading indications, equipment unavailabilities, and other unusual configurations or operational circumstances). ATHEANA was developed to address limitations identified in current HRA approaches by addressing errors of commission and dependencies, more realistically representing human-system interactions that have played important roles in accident response, and integrating advances in psychology, with engineering, human factors, and PRA disciplines.

Research Status:

ATHEANA has completed several stages of development including field testing. NUREG-1624 "Technical Basis and Implementation Guidelines for a Technique for Human Event Analysis (ATHEANA)- Draft for Comment“ provides the concepts upon which ATHEANA is built, practical guidance for carrying out the method, and a description of the current status of the technique including the results of the field tests.

NRC: Management and Organisational Factors in PRA

Research Entity:	The Idaho National Engineering and Environmental Laboratory (INEEL)
Sponsor:	USNRC
Objective:	To develop and demonstrate practical methods that allow for the integration of management and organisational factors in risk assessment activities.

Research Background:

INEEL conducted a „Workshop on Management and Organisation, Performance and the Regulatory Framework“ in August 1997. The workshop participants were subject matter experts from diverse fields including risk management, human factors, organisation and management, and nuclear power plant operations. Key management and organisation issues and factors were identified along with candidate performance measures and ratings of technical basis for these factors. Following the workshop, an annotated bibliography was developed to provide information about the relationship between the identified factors and performance. In addition, INEEL developed a modelling framework „The Socio-Technical Contribution to Risk Assessment and the Technical Evaluations of Systems (SOCRATES)“ which extended the findings of the workshop and was intended to aid conceptualising the role that organisational factors play in shaping plant performance and how they influence risk.

Research Status:
This research project has been discontinued due to changes in research priorities.

The Obninsk Scientific Centre «Prognoz» (Russia): A Longitude Verification of the Organisational Factors's Influence on Nuclear Power Plants' Reliability

Main Researchers:	Vladilena N. Abramova and Eduard V. Volkov
Sponsors:	State concern «Rosenergoatom» of the Russian Ministry of Atomic Energy.
Collaboration:	Russian NPPs and PPAL (Psycho-physiological Assurance Laboratories)
Objectives:	Identifying the influence of organisational factors on human performance effectiveness. The researchers developed a database, which groups together information on individuals working at «Rosenergoatom» nuclear power station over a 10 years period (more than 6000 individual investigations) and information on

various organisational factors. Originally, the hypothesis of this research group was that the evolution and the variation of the psychological profiles of plant personnel could be explained by the influence of organisational factors. Abramova claims that her group has succeeded in confirming this hypothesis. Researchers are also interested by identifying psychological profiles that are more resistant, more robust to organisational change.

Publications: Abramova, Volkov, Mefodiev and Gordienko (1998); Abramova, (1997, 1996, 1995); Abramova, Mefodiev and Volkov (1997); Abramova, Baumont, Frischknecht and Tolstykh (1996); Abramova, Belehov et al. (1990).

Research background:

The needs for psychological assessment in operational events in Russian nuclear power plants have led psychologists to use quantitative methods for analysis of "direct" and "indirect" (root-causes) causes of human error. The main focus of the practical method of investigation is on the individual who makes an error. In this method, NPP socio-technical system elements are considered as the external conditions, affecting correctness or errors of actions.

On one hand experience shows that a human error depends also on professional competence, motivation and some professionally important psychological qualities, his functional state, psycho-physiological qualities, characteristics of mentality, attention and memory. On the other hand, in an emergency situation successful personnel performance is mainly affected by psychological professional important qualities such as high level of self-control; thoroughness and conscientiousness and so on.

High-quality quantitative methods of human characteristics measurement and of the influence of characteristics on safety have also to be connected to organisation reality such as the socio-political situation and the socio-economic working conditions of the personnel of nuclear stations. They are also important factors of safety.

Hence, in the Human factor area, the Russians have always been strongly involved in measurements of Human Performance, using psychological methodologies and tools (such as «attitude questionnaires», «16 PF test scales», «MMPI» which are widely used in the psychological community). Nuclear power plants have all developed database on their personnel psychological profiles. It is not necessary to mention the traumatism that *Chernobyl* caused to a research community, mainly trained in psychology as Abramova and Mefodiev explain «..after Chernobyl accident, the psychological service needs to refocus on assurance of social-psychological condition of reliability and furthermore organisational influences on nuclear safety».

Research apparatus:

The originality of the «Prognoz» program is that it kept existing psychological database, and enriched it with a set of organisational factors over a 10 years period. Prognoz researchers can access the «Rosenergoatom» database on line.

They are considering the following Organisational Factors, divided in two categories:

External factors

- Political climate in Russia and in the NPP local region
- Intention to safety
- Distribution of responsibilities
- Manager selection
- Manager position
- Analysis of NPP operation
- Personnel training
- Workload
- Ergonomics characteristics
- Socio-psychological work conditions

Internal factors

- Motivational factors defining motives and psychological attitudes to productive work and high safety culture
- Professional knowledge, showing professional readiness to work
- Professional behaviour
- Psychological states of workers
- Psychological state including affective states of stress, affect, frustration, loss of life sense and so on.

In addition the database contains information about events and incidents involving plant personnel.

The determination of the factors, influencing a worker psychological profile, is carried out in several stages.

- Determination of "zones of risk" in socio-psychological climate according to socio-political and socio-economic factors;
- Study of their condition;
- Prognosis of influence of the socio-psychological state of the personnel on NPP safety.

Some results:

Prognoz researchers have identified a quite robust psychological profile for people working in a Nuclear Power Plant: despite the variations from one individual to another, when they are aggregated, psychological profiles are very close. This result has to be compared with population profiles in general which do not show such a regular and robust profile when aggregated.

Prognoz has identified three different groups of people: a) a «risk» group; b) a group of statistical norm; c) a reserve group.

Prognoz has identified and described the psychological evolutions of a sample of 100 persons.

Prognoz in co-operation with utilities and with Psycho-physiological Assurance Laboratories (PPAL) contributed to the creation of NPP norms and regulations for measuring human factor parameters. They also contributed to change the personnel selection process according to the research findings.

This research centre contributed also to the establishment of worker support programs.

Research status:

The research program is now continuing and developing along the following lines:

- Analysis on dynamics of individual examination results an example of the mentioned 100 persons from of control room personnel: for risk group (30 person), group of statistical norm (40 persons) and reserve group (30 persons) during 10 years by a complex of techniques: Behavioural observations, structured interviews, document analysis, event review, questionnaire, workshop and trend analysis.
- Analysis of the dynamics of socio-psychological, socio-political and economical events for the period by questionnaires, document analysis and structured interviews.
- Analysis on the peculiarities of Nuclear Power Plant organisational transformations for the period by document analysis and structured interviews.
- Analysis of the characteristics of the socio-psychological climate in teams by structured interviews and questionnaires.
- Analysis of family events for the population under investigation by structured interviews.
- Determination of causal relationships between successful personnel activity and data sets given in the analysis by comparison of the results from the implementation of the complex of mentioned techniques with the results of individual psychological and psycho-physiological data of the personnel.

The OECD Halden Reactor Project (Norway): The integration of Organisational Factors in PRA/HRA

Main Researcher:	Erik Hollnagel
Sponsors:	The OECD country members
Objectives:	Hollnagel's research project is aiming at developing a new PRA, called CREAM [for Cognitive Reliability and Error Analysis Method], designed to take into account the organisational contexts of the events under study.
Publication:	Hollnagel (1996, 1998)

Research Background:

Hollnagel's project embraces a new challenge that is facing PRAs designers. Disasters such as *Chernobyl*, *Challenger* and *Bhopal* have contributed to placing organisational aspects of complex socio-technical systems in the foreground of PRA/HRA research agenda. Hollnagel argues that traditional PRAs cannot simply be extended to cover «organisation and management». As the researcher puts it: «At the present we are therefore faced with the challenge to account for how an overall account of the factors that affect event occurrence and development can be included in the established methods of safety and risk assessment, in particular of how management and organisation factors can be treated in PRA». A new PRA like CREAM (or ATHEANA) is an attempt to take up the challenge.

Some elements about CREAM:

The Cognitive Reliability and Error Analysis Method describes the context of the work situation being analysed (i.e., the PSA event tree) by means of 9 so-called Common Performance Conditions. Common Performance Conditions describe the general determinants of performance, hence the common modes for actions in a context. They include: 1) adequacy of organisation; 2) Working conditions; 3) Adequacy of Man-Machine Interface and Operational Support; 4) Availability of procedures/plans; 4) Number of simultaneous goals; 5) Available Time; 6) Time of day; 7) Adequacy for training and experience; 8) Crew collaboration quality. These CPC are then used as a basis for a qualitative identification of the likely error modes, followed by a quantification of the probabilities of their occurrence. The two steps must be carefully separated.

These Common Performance Conditions allow to capture important organisational aspects such as culture and climate, organisational structure, management style, worker attitudes, explicit and implicit goals, personnel training, organisational learning, communications, organisational problem identification and problem solving and general resources.

Status of the research:

Still under development.

The Korea Institute of Nuclear Safety Project: Organisational Factors, identification and Assessment

Main researcher:	Sok-Chul Kim, Safety Analysis Department
Objectives:	The goal of this research project is first to identify the influential factors in terms of organisational factors such as leadership of the shift supervisor, communicational quality, and procedural characteristics on team performance during an emergency situation such as LOCA or SGTR in nuclear power plant. The second and main objective is to use these results in order to refine the HRA methodology.
Publication:	Kim and Lee (1997, 1995); Kim et al. (1996, 1997)

Research background:

The research project agenda is based on the following statement: current human reliability analysis in Probabilistic Safety Assessment (PSA) has limitations in many respects. Notably, Performance Shaping Factors do not consider how crew organisational characteristics and procedure characteristics (in terms of their format) are impacting the way operators are using them. In EOPs, Operators are too often believed to work alone, while it is often the contrary: they are sharing sets of tasks. The accident of the Challenger space shuttle, the Three Mile Island and the Chernobyl made clear that ineffective team performance emerged as a specific area of interest for HRA. In a first phase, the project started with a literature review on PSA/PRA methodologies, which reveals that a complete understanding or consideration of organisational factors related to team performance does not exist in the nuclear safety field.

One should also notice that this project is part of a national long-term research project called «Development of Severe Accident Assessment Regulatory Technology for Nuclear Power Plants», which started in 1993.

Research apparatus:

In order to identify influential organisational factors on team performance, empirical research has been conducted at two types of nuclear Power plants: 1) Four Westinghouse PWRs Units ; 2) Two Framatome PWRs Units. Currently, 6 Candu plants and a couple of Korean Standardised Nuclear Power Plants (KSNP) are been investigated also. For this empirical investigation, two types of full-scale plant simulators [Kori Nuclear Training Center and Ulchin] were used with 19 on the job MCR crews taking part in simulators tests. Crews have been working on two famous scenarios - the LOCA and the SGTR.

All crew behaviours were videotaped for time-line analysis and to evaluate team-work and communicational quality of the crew during the accident mitigation process. Experience and expertise levels of each crew has been investigated for identification of organisational characteristics through questionnaires prior to simulator testing.

Nineteen teams of 122 individuals coming from three different sites participated in the study.

According to Crews' organisational characteristics, in terms of age, academic background, current position, seniority, past experience, the crews were split into three categories:

> Cat 1 - The first one, includes 6 crews shows a strong Shift Supervisor (seniority of at least 5 years in the position)
>
> Cat 2 - The second one, includes 10 crews shows an equal or less experience from the shift supervisor and the STA's part compared with operators.
>
> Cat 3 - The third one, includes 3 crews, shows that some members of the crew have a deficit of experience, especially STAs or operators.

The main empirical results show that according to each crew profile, management of the accident mitigation differs. Other parameters are also studied by Kim, like procedures' format and degree to which task allocation is specified in EOP, however we will not report on these ones (for a complete description of the protocol and the results, see Kim's contribution to the workshop, «Empirical approach for team performance evaluation on crew composition and procedure types»).

> Teams belonging to cat 1 showed good inter and intra-communication and fast-recovery actions, related to performance measures based on the directions given by the shift supervisor. Some differences were found between plant type and the way work is allocated.
>
> Teams belonging to cat 2 showed a delay of 10 minutes as compared to teams in cat 1, in isolating faulted steam generator.
>
> Teams belonging to cat 3 showed a greater delay and a difficulty to manage the accident scenario. However, results show that no group were found to have committed significant error which might have caused an accident: all group identified the SGTR scenario in less than 150 seconds.

The research results have led to the following recommendations:

- It is very important that shift supervisors or STAs have initiative in the process of accident mitigation in order to best supervise team co-ordination
- In recruiting MCR crews, the difference of the relative experiences or expertise level among the crew members should receive proper consideration
- Task allocation should be clearly specified in the EOP

Research status

The research continues on CANDU and Korean design plants. The introduction of the results have still to be integrated into PRAs.

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