COMMISSION OF THE EUROPEAN COMMUNITIES
FOURTH FRAMEWORK PROGRAMME ON NUCLEAR FISSION SAFETY

CONTRACT No. ERB FI4S-CT98_0051

ORGANISATIONAL FACTORS; Their definition and influence on nuclear safety (ORFA)

Report on Needs and Methods

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Distribution of this document is restricted to Partners in the Project

May 1999 AMM – ORFA(99) – R03

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1. Background

1.1 The ORFA project

A Concerted Action within the Nuclear Fission Safety Program has been started under the Contract N° ERB FI4S-CT98_0051 of the European Commission between the parties *VTT Automation*, Finland, *Ciemat*, Spain, *Nuclear Safety Directorate*, United Kingdom, *HSK*, Switzerland, *IPSN* France, *Berlin University of Technology*, Germany and *Vattenfall Energisystem*, Sweden. All partners in the consortium have ongoing activities which are relevant to the subject and are eiterh regulator or have close ties to nuclear power utilities and regulators. The project began on 1 August 1998 and is planned to end in December 1999.

A number of organisations worldwide recognise the importance of organisational factors in nuclear safety. The project addresses nuclear safety on a broad basis and once results are shared and agreed by the research team this may serve as a guide on how to approach organisational factors as a component of nuclear safety in future. The Concerted Action has two basic objectives:

i. to join scattered European resarch efforts in organisational factors of nuclear safety and establish a common frame for future research in the field.

ii. to identify key components of a theoretical framework which can be used to assess organisational aspects of safety at nuclear power plants.

The work is divided into three work packages:

(1) *Needs and Methods*, described in this report, May 1999,

(2) *Final Seminar*, to be held in Madrid 21-22 October 1999,

(3) *Major Conclusions,* described in the final report due in December 1999.

1.2 Needs and methods

Organisational factors may arise from various sources.

Over the last quarter century, the whole nuclear community has experienced large environmental changes and this has led to considerable changes at nuclear power plants. Sometimes nuclear power plants have experienced various problems which have led to reconsidering the way they organise and manage work. Regulators have often explicitly included a requirement to look at organisation and management in recent periodic safety reviews.

On a generic level there are three types of needs:

- Assessment (how well does the organisation perform, what are the main problems),
- Design (what is a feasible way to structure a certain activity, how can certain problems be avoided),
- Operation (how can the organisation be operated and maintained).

Methods are always adapted to the needs seen when a specific task is initiated. Unfortunately there is no general toolbox of methods available for assessing organisational factors. That means that when a specific need is identified an ad hoc method will be developed either based on what is available from the literature or else via consultants. Sometimes methods are searching for possible needs (potential applications) rather than the other way round..

Methods should always be based on a more or less formal theory which can be used to generate hypotheses which can be tested. Unfortunately, many of the proposed methods do not have an underlying theory which implies that the results obtained may be difficult to interpret.

Working Package on needs and methods

The goal of the working package on needs and methods was to collect existing methods for assessing organisational factors and identifying needs for future research on this topic. Berlin University of Technology, Research Center Systems Safety (FSS) conducted the "Needs and Methods" work package. In preparing the work package, FSS

- collected and described general organisational strategies for the assessment of organisational performance (chapter 2)
- produced a synopsis of different models of organisational factors by collecting 13 models which seemed to have a substantial input into the project. Chapter 3 describes these models in a standardised form. (For a synopsis of the content of these models see appendix A)
- identified 7 general categories using the "meta-plan" method - a technique to structure a complex domain into its constituent parts (appendix A). To summarise and visualise the potential interrelations among the seven categories and their influence on nuclear plant outcomes, FSS constructed a generic model with 8 general categories (chapter 4).
- drafted a survey on needs and methods for NPPs and regulators, consisting of 9 questions about assessment of organisational performance. Where possible, project partners contacted competent co-operating experts to collect views on needs and methods. Comments of the partners on the application of the survey were collected as a basis for further discussion (chapter 5).

2. Organisational strategies in use

In general, nuclear power plant operators understand the contribution that organisation and management factors can make to performance. They therefore use many practices and strategies in which organisational factors are relevant. The organisational factors and their presumed causal relationships are, however, implicit in the practices used. The ORFA project assumes that by making these relationships more explicit it should be easier to clarify and maintain a suitable overview and thereby afford better control of safety. The items below provide examples of strategies and practices which have, from to time, been adopted in response to perceived needs within the safety management process. The list is not exhaustive.

Quality systems

Nuclear power plants use quality systems as a general method to ensure that the quality of work is fit-for-purpose. Quality systems rely on a agreed definition of quality and a description of the procedure needed to attain the specified level of quality. Quality systems also specify regular internal audits to ensure compliance with the quality systems. These audits are typically performed by small teams which include subject matter experts, peer reviewers and quality managers. During an audit, the audit team will assess a specific part of the organisation or a specific work process in detail, and produce a report on its findings and recommendations. Over the last twenty years, various phases of the application of quality systems have been observed in the nuclear industry. As might be expected, it took some time for the first quality systems in to be put in place and become functional. Initially, these systems were often rather prescriptive, and problems were sometimes experienced in getting them accepted within affected organisations. Modern quality systems tend to be less prescriptive, more goal-oriented, and emphasise requirements associated with the work processes as well as the resulting products of their application.

Activity planning

Nuclear power plants, like many other organisations, undertake a yearly cycle of activity planning. Particular importance is placed on the planning of refuelling outages which are also used to create opportunities for carrying out modifications, maintenance and repair work. Typically, plants take a 3 or 5 year forward strategic look which is then converted to annual plans which, in turn, form the basis for budgeting and resource allocation. The annual plan is usually revised based on an assessment of the previous year’s results. Refuelling outages are particularly important and are planned in great detail so as to minimise the downtime of the plant concerned.

Performance appraisals

Performance appraisals are used at many nuclear power plants as a systematic tool to assess performance and set personal goals. The appraisals are a discussion between the jobholder and line manager, as part of an agreed appraisal scheme. During the appraisal, both the jobholder and line manager discuss performance since the last appraisal and usually agree what tasks need to be accomplished during the next review period.

Organisational restructuring

Nuclear power plants typically have a formal organisational structure, with authority and responsibilities described in organisational handbooks. Traditionally there is a clear line of command through the organisation where each person reports to an identified superior. In many organisations, this approach has tended to change to a matrix approach whereby tasks can cut across several lines within the organisation. In some cases this type of organisational change has caused problems of co-ordination.

Business Process Re-engineering within the organisation

Over the last twenty years there has been a subtle shift in power from the technical department to operations in some European power plants. In some places this has resulted in the technical department's supplying work to orders from the operations department. This clarification of the roles has tended to be well received where it has been implemented, but, in some cases, it has also resulted in a dilution of responsibilities.

Safety committees

Many European nuclear power plants have formed safety committees. The mission, organisational placement and composition of the safety committee varies, but they are generally similar. The safety committee's role is to advise on various safety issues and they often approve incident reports, PSAs, audit reports, plant modification proposals, safety cases, etc.. Safety committees have formal links with the regulator, whereby the latter receives meeting minutes and, sometimes, participates in meetings.

Exchange of good practices

The nuclear industry as a whole has been exceptionally willing to share good practices irrespective of company and organisational borders. This sharing has been systematised by WANO and INPO, but IAEA has also played an important role in various programmes. Peer reviews have also been instrumental in sharing good practices, although this is not their main function. Opportunities for managers to visit to other plants to see different practices is also important in promoting a better understanding of impacts of management on performance.

Regulatory framework

All nuclear countries have their own regulatory framework, some more prescriptive than others. Despite this, practices on a general level tend to be similar, whilst differing at a more detailed level. The regulatory framework, therefore, contains, at least implicitly, a model for how a nuclear power plant should structure its work. The regulatory framework and how it is interpreted has a large influence on how the regulator and nuclear power plants communicate.

Safety culture

The concept of safety culture was formulated by IAEA after the Chernobyl accident. Though the concept has world-wide support, it is interpreted in several different ways. The concept forms part of nuclear legislation in some countries, where it has been said that the nuclear power plants are responsible for maintaining a good safety culture. The difficulty is evaluating whether a good safety culture is in place. In response, IAEA has developed its ASCOT methodology which has been used successfully for some self-assessments. The problem, however, with the safety culture concept and the ASCOT methodology is that the references to the theory of organisation and management are somewhat tenuous. That tends to make it difficult to use the methodology to its fullest extent. (A list of seven standardised analytical tools for the assessment of safety culture and safety climate can be found in appendix B).

Probabilistic safety analysis

PSAs are used as a tool both for assessing safety and for targeting modification needs. Ideally, a PSA should be able to include the technical, human and organisational systems, but the level of modelling is not at the same level in these three areas. The PSA models of the technical systems tend to be quite detailed, with some human errors typically being included, and modelled. However, whilst it is apparent that the safety of the nuclear power plants can be influenced by organisational performance, few, if any, PSA models reflect the impact that might be exerted by such organisational factors.

Peer reviews

Most nuclear power plants have been involved in peer reviews in one way or another. IAEA, for example, offers peer reviews to member states within the OSART, ASSET and ASCO programmes. WANO and INPO offer similar peer reviews to their own members. A peer review is carried out in a similar way to a quality audit, but the scope of the assessment is far broader. An OSART review can typically involve 15 people for three weeks. When peer reviews are initiated the organisation to be reviewed often carries out an internal review before the peer review starts.

Incident analysis.

All European nuclear power plants have systems for analysing incidents occurring at their plants. The detailed methods vary, but they are generally very similar in application. The methods are generally good at detecting technical problems, but they are not as good at identifying human or organisational causes. To obtain a true picture of events, an incident analysis has to be carried out in a "no-blame but fair" atmosphere. It should always lead to recommendations for improvements which aim to eliminate the cause, making it impossible for similar incidents to reoccur. Observations from nuclear power plants point some difficulties in making workable recommendations using this approach.

Performance indicators

Most European nuclear power plants use WANO-indicators to measure their performance. The indicators are not intended to compare nuclear power plants, but do give feedback to plant managers on how their plant's performance compares with other plants. Some of the nuclear power plants have discussed amending the WANO-indicators to include additional indicators which would be more sensitive to detecting worsening performance. By integrating performance indicators into the activity planning system, for example, a systematic framework for performance evaluation and improvement could be constructed.

Assessments of the organisational climate

Many nuclear power plants have assessed their organisational climate using questionnaires. The questions are typically directed more towards how people enjoy their work than towards safety issues. Some of the interpretations from these studies can contribute to organisational performance. The translation of the results into improvement actions has proved difficult, but the method can generally give some indications of underlying factors. (A list of seven standardised analytical tools for the assessment of safety culture and safety climate can be found in appendix B).

Self-assessments

All nuclear power plants are involved in self-assessments of various kinds. Incident analysis is one form of self-assessment and quality audits are another. Some NPP organisations have gone through self-assessments which are based on the standard peer review techniques. One commonly used scheme for self-assessment is also the list of items considered in awarding quality prizes.

Certification

Many nuclear power plants have implemented or decided to implement quality systems certification. Some plants have implemented and certified an environmental monitoring system. Certification involves a formal audit against an applicable standard. The certification process provides a good opportunity to evaluate and improve work processes. In some cases, the certification process places a heavy burden on resources.

3. Synopsis of models of organisational factors

For the synopsis of models of organisational factors, the following 3 steps methodology was applied.

Step 1 - models of organisational factors from the literature were collected.

Step 2 - general categories of organisational factors were identified, using the “meta-plan” method. This is an interactive problem-solving technique in teams to structure a complex domain into its constituent parts.

Step 3 - a generic view on organisational factors was developed from the general categories (chapter 4).

After a review of relevant literature, 13 organisational models were selected, all covering various organisational factors. These models are listed below (3.1 to 3.13). This list is not exhaustive but is a sample of the models of organisational factors found in the literature. All models are described in a standardised form, addressing the background and other overall aspects of the approach, the theoretical basis and definition of the organisational factors, the description of organisational factors including the overall number of categories, sub-categories, level of detail, and the method for the assessment of organisational factors. In appendix A, the principal factors of the models are presented as a synopsis.

Each model was selected based on a qualitative assessment of its relevance, provided that information about the model is available. The models span a wide range from theoretically founded models (e.g. CREAM) to empirically founded models (e.g. NRC). Some models contain a prescription on how to assess organisational factors (e.g. NRC), others do not. The synopsis of models of organisational factors revealed some more general problems and difficulties:-

- The model itself, which underpins behind the list of factors, is not always made explicit.
- The difficulty of language: people do not always mean the same thing even with the same words.
- There is an implicit underlying assumption that NPPs have organised themselves in a certain way, which is not made explicit.
- The general cultural difficulty: methods or models are not always transferable between cultures.

3.1 NRC model of organisational factors (A)

During extensive research, Jacobs and Haber (1994) reviewed studies and reports about incidents in the nuclear field as well as related fields for the US Nuclear Regulatory Commission (NRC) to gather information on the parameters of safety from an organisational perspective. Using this broad empirical base, Jacobs and Haber established twenty organisational factors which are linked to safety and which were repeatedly mentioned as precursors of explanations for unsafe operations. These factors were grouped into five categories that help to organise the organisational factors. The work of Jacobs and Haber has had an important influence on the research of organisational factors in the nuclear domain, especially in the USA. For example, the organisational factors which were identified, were incorporated in the WPAM method (Apostolakis, 1999) for modifying probabilistic safety assessments (PSA) in order to provide a prediction concerning the effects of organisational changes on safety and to reduce their uncertainty.

The methodology of NRC is an empirical approach, which is based on a large database. It is the inherent logic of this type of approach not to begin with a theory-driven a priori definition of ORFA. Jacobs and Haber defined 20 dimensions which reflect the perceived status of common understanding of organisational factors as they influence safety. These have been grouped into the following 5 categories:

1. Administrative knowledge

- *Coordination of work*
- *Formalization*
- *Organizational knowledge*
- *Roles and responsibilities*

2. Communications

- *External communication*
- *Interdepartmental communication*
- *Intradepartmental communication*

3. Culture

- *Organizational culture*
- *Ownership*
- *Safety culture*
- *Time urgency*

4. Decision making process

- *Centralization*
- *Goal prioritization*
- *Organizational learning*
- *Problem identification*
- *Resource allocation*

5. Human resource allocation

- *Performance evaluation*
- *Personnel selection*
- *Technical knowledge*
- *Training*

Each of the 20 dimensions is well defined, e.g the dimension “ownership” means “the degree to which plant personnel take personal responsibility for their actions and the consequences of the actions. It also includes commitment to, and pride in, the organization”.

Jacobs and Haber describe four techniques for assessing the 20 dimensions. A survey has been created to collect information on the dimensions. Behavioural checklists using key statements about observable events are linked to each of the organisational dimensions. The checklists allow data to be collected by walking through the plant. Structured interviews are conducted with people responsible for various aspects of safety. An established method for assessing individuals' performance BARS (Behaviorally Anchored Rating Scales; Jacobs, Kafry & Zedeck, 1980) was transformed to facilitate the assessment of organisations. Each of the 20 organisational dimensions identified is measurable by two or more assessment methods.

The work of Jacobs and Haber is part of a regulator-initiated research program of the US NRC on the assessment of organisational performance of NPP.

3.2 Swiss Federal Nuclear Safety Commission (B)

Based on the IAEA Convention on Nuclear Safety of 1994, which lays down in general terms the obligations for legislation and operators regarding the safety of nuclear installations, the Federal Council of Switzerland imposed the requirement to include safety culture in general safety consideration for NPP. In 1995, the Swiss Federal Nuclear Safety Commission (KSA) created a working group with the aim of promoting and clarifying the safety culture concept in Swiss NPP. A document was drawn up, which outlines the objectives and the definition of safety culture, the essential elements of safety cultures and methods to assess them.

As with many other research studies in the field of nuclear safety, the definition of the term “safety culture” of the KSA follows the definition of safety culture of the IAEA published in INSAG-4 (1991). “The term ’safety culture‘ denotes an underlying safety-oriented attitude at all hierarchical levels. Each individual staff member is required to be aware of his responsibility for safety, and have the ability, means and authority to assume the responsibility” (KSA, 1996, p.4). Safety culture consists of two main components:

- responsibility of management to implement a safety-oriented philosophy, to create an appropriate organisational structure and to make the necessary resources available
- attititude and conduct of personnel at all levels and how they communicate.

Apart from this definition, the KSA document offers a detailed description of elements of safety culture. Safety culture consists of “technical aspects”, “hierarchical task allocation”, “organisation” and “events”. Those elements which are summarised in the chapter on “organisation” could be described as the organisational factors of the KSA approach:

- *Safety objectives*
- *Collaboration between organisation units*
- *Quality management*
- *Operation*
- *Maintenance*

- *Technical support*
- *Radiation protection*
- *Industrial safety*
- *Attitudes to staff*
- *Training*
- *Emergency operation*
- *Safety review*

In the KSA document, methods are mentioned, which help to identify and promote safety culture. Although many instruments and tools are summarised in this paper, it is not clear which of these instruments are in use in Swiss NNP. According to the authors, research on safety culture has been performed mostly via questionnaires and interviews. Possible interview questionnaires are the "questionnaire on work and treatment of safety" developed by the Department of Industrial Psychology at ETH Zurich, (Grote & Künzler, 1994) and the ASCOT Guidelines of IAEA (1996). These questionnaires are criticised as beeing too general and insufficiently related to real situations. Therefore, Semmer and Regenass (1999) developed the "situational approach" in order to get deeper than the interrogation level in questionnaire applications and interviews. This situational approach consists of three main stages:

1st - experts on Human Factors and NPP experts gather situational scenarios which are linked to safety.

2nd - these situations are discussed with staff, individually or in groups relating to various aspects (thoughts/fear, action, communication).

3rd - Discussions are evaluated and judgements are made, e.g. on weaknesses, training and safety culture.

The model of KSA was drawn up to clarify the safety culture concept, i.e. the objectives and the definition of safety culture, their elements and to give an overview of assessment methods. The document was drawn up to support the Swiss NPP in applying the safety culture concept for their organisational assessment.

3.3 OECD/NEA Principal Working Group No. 1, Task 7 (C)

The Organisation for Economic Co-operation and Development (OECD) founded the Nuclear Energy Agency (NEA) in 1972 with the objective to promote co-operation among the members of NEA on questions of nuclear safety. Root cause assessments of events identified very often weaknesses in organisational factors as contributing to events. There is general recognition that organisational factors need to be evaluated for their contribution to plant safety performance to prevent their recurrence in events. A special recommendation to create a SOAR (state of art report) on the organisational aspect of safety was presented in the NEA report on Research Strategies for Human Performance (NEA/CSNI/R(97)24). Based on this recommendation the Principle Working Group 1 (PWG1) requested, as a top priority, that the Expanded Task Force (ETF) on Human Factors develop a SOAR for the September 1998 meeting. The ETF members were convinced that there was a need to collect and analyse operational and event data from the nuclear environment to determine the safety and risk significance of organisational factors, to identify assessment methods for those factors used in the different countries and to gain peer review of the results to ensure credibility and acceptability of these methods and possibly their measures. The aim of this meeting, that was held in 1998 in Switzerland, was to identify relevant organisational factors and methods for their assessment. A SOAR on organisational factors' identification and assessment was the result of this meeting. Due to the fact that the workshop was an expert meeting, the theoretical basis for organisational factors comes from different approaches and theories. For each of the factors a definition is provided. Further aspects of the factors and clarifications are given to provide a complete picture of the organisational factors. Twelve organisational factors were identified as important to assess by ETF in determining organisational safety performance:

- *External influences*
- *Goals and strategies*
- *Management functions and oversight*
- *Resource allocation*
- *Human resources management*
- *Training*
- *Co-ordination of work*
- *Organisational knowledge*
- *Proceduralization*
- *Organisational culture*
- *Organisational learning*
- *Communication*

The aim of the workshop initiated by ETF was not to develop new methodologies for gathering information about organisational factors but to foster and summarise existing methods. Assessment approaches proposed by ETF are subdivided into approaches used by utilities (monitoring organisational functions through self-assessment), approaches used by regulators (proactive assessment, reactive assessment and assessment of corrective actions) and recent research trends (theoretical basis data to develop assumptions and to test hypotheses). The different assessment approaches of the member states of NEA were collected and described in order to share the practices used. The rationale of the assessment methods can differ a lot from one country to another, depending on the regulatory context and the culture of the country.

The ETF was established because of a perceived lack of assessment methods for the contribution of organisational factors to events in NPP. The basic demand was the identification of relevant organisational factors and their assessment methods.

3.4 HSE Health and Safety Management (D)

Much of the research work performed by the safety authorities of the UK Health and Safety Executive (HSE) has been in the chemical or petrochemical industry fields. The goal was to develop a method to incorporate organisational and management factors in Quantitative Risk Analysis (Hurst et al, 1990; Bellamy et al, 1991).

The theoretical basis was established through the development of a model, the so-called "Sociotechnical Pyramid". The model has a broad empirical database (e.g. analysis of Piper Alpha and other accidents), but is also based on existing theoretical management models. The Sociotechnical Pyramid defines a hierarchical scale of accident causation from the most immediate factors to the most remote factors. It consists of five levels which are the main categories of organisational factors:

- *System climate*
- *Organisation and management*
- *Communication and feedback*
- *Engineering reliability*
- *Operator reliability*

These categories consist of several subcategories, which are:

Level 1: The system climate: This level describes factors, which are not under the control of a company. It includes

- state of knowledge of the industry in general,
- industry norms,
- activity of legislation and regulatory bodies,
- political or financial pressure.

Level 2: Organisation and management: This level describes factors, which are influenced by the organisational and management structure of the plant. It includes:

- Policy (goal setting, leadership)
- The organisational structure (operational, maintenance, safety and training structures)
- Defined responsibilities (clear roles and responsibilities; mechanisms for control)
- Site standards (setting, maintaining and improving site standards)
- Resources (setting of budgets, deadlines and ground rules)
- Information (policy on the use of data from monitoring, auditing and inspections)
- Reward and punishment system.

Level 3: Communication and feedback: This level consideres management processes and includes all elements of communication and coordination.

- Formal and informal communication (written and verbal)
- Documentation
- Man-machine interface
- Communications hardware
- Supervision and inspection
- Monitoring, feedback and program evaluation.
- Data presentation

Level 4: Operator reliability: This level describes those factors which depend on the reliability of the operator. This includes:

- Demands and design of tasks
- Operator selection
- Man-machine interface.

Level 5: Engineering reliability: This level describes those factors which rely upon the control of the plant design. This includes:

- Failure analysis
- Instrumentation and control
- Ergonomic weaknesses.

The authors added another level, the Level 0, which describes those factors which help to mitigate the actual impact of an event, e.g. automatic shut off valves, water sprays, venting systems. This level cannot be integrated in organisational factors but should be mentioned to complete the picture.

On the basis of the theoretical model, two tools for assessing management and organisational factors in non-nuclear industries have been developed:

- Questionnaire to measure the attitude towards safety - SAQ (Safety Attitude Survey Questionnaire)
- Safety management audit system called STATAS (Structured Audit Technique for the Assessment of Safety Management Systems) (Hurst and Ratcliffe, 1993).

Assessment of Health and Safety Management is part of the regulator's activity in organisational assessment in the UK industry. Techniques that are used take account of the developmental activity described above, but are not confined to these approaches.

3.5 Finnish Safety Evaluation Memorandum (E)

The Finnish Safety Evaluation Memorandum should be seen as an answer to the new safety regulations issued by the State Council of Finland in early 1991. The new demand on safety was to integrate safety culture in current safety concepts. To provide a practical basis for the systematic introduction of safety culture, the Finnish Nuclear Regulatory Body (STUK) conducted several training sessions for all engineering and supervisory staff. In these sessions those safety indicators which are documented in INSAG-4 (1991) were used for self-evaluation. Several training sessions were held to maintain and improve the results of the self-evaluation. In a parallel activity, STUK trained its own personnel on this topic.

The theoretical basis of this Finnish approach follows the theoretical thesis of the INSAG safety reports. Theoretical assumptions of INSAG and their definition of safety culture can be found in part 2.9. The safety evaluation memorandum includes the following organisational factors :

- *Decisions of the corporate and plant management*
- *General housekeeping at the plant*
- *Resources invested in maintenance of the high safety level*
- *Efficiency of the management system in ensuring implementation, co-operation and exchange*
- *Methods and maintaining and upgrading the professional skills*
- *Adequacy of plant procedures*
- *Rewards to the plant personnel*
- *Preparedness of the plant management to the subject of assessment*
- *Attitudes of the individuals to their duties*
- *Openness in uncovering and solving problems*
- *Systematic assessment and development of the plant safety*
- *Resources invested in safety relevant plant modifications*

The assessment of the organisational factors described above is based on the safety culture indicators of the INSAG working group, which can be found in the INSAG-4 safety report, appendix section A 2. During their research work, the Finnish Nuclear Regulatory Body developed their own assessment method through modification of INSAG-4. It can be found in the appendix 2 of “Safety Culture-The Finnish Approach” (Laaksonen, 1996).

The Finnish activity is a reaction of the regulator to the perceived needs to clarify the INSAG 4 concept of safety culture. It was also prompted by the need of safety assessments in connection to the renewal of plant operation licensees in Finland. Performance indicators were developed for a safety culture self assessment methodology.

3.6 Swedish “Factors to Promote Continuous Improvement Organisations” (F)

The Swedish Nuclear Power Inspectorate (SKI) follows two concepts of regulatory policy: the first is the formal regulatory and supervisory role and the second is the active promotion of safety improvements. Based on this second aim of regulatory policy, SKI developed an approach for the analysis of the impact of organisation on nuclear safety in collaboration with Battelle Human Affairs Research Center, USA (Dahlgren, 1994). They developed a concept, including the most important characteristics of a continuous improvement organisation (CI) and a method to assess it. The theoretical background of this approach is a transformation of management theories of continuous improvement like the Japanese model or The Fifth Discipline (Senge, 1990). Its application to nuclear power plant safety includes the following points:

- CI organisations define their goals and all activities are oriented towards these goals.
- CI organisations are dominated by strategies (i.e. schedules, performance objectives...).
- CI organisations take the responsibility for their plant.
- CI organisations value expertise and foster all kind of relevant information.
- CI organisations are participatory with respect to their results of analysis and expertise.

The continuous improvement approach implies the evaluation of four key processes: strategic decision making, aligning the organisation, managing change, and organisational learning. Concerning the organisational learning (OL), SKI and Battelle identified the elements of an OL model described below. These elements replace organisational factors as they are known from the other approaches.

The elements of OL are developed along the needs of CI organisations without defining their field of application. Based on the theoretical considerations, the OL model consists of the following elements:

- *Problem solving*
- *Problem diagnosis*
- *Solution formulation*
- *Solution implementation*
- *Assessment*
- *Feedback*

In terms of assessment, SKI has various methods to gain information on organisational factors. Possible sources are:

- Operating experience, which means reportable events (LER- Licensee Event Report) and incident analysis and periodic safety reviews (ASAR- As Operated Safety Analysis Report).
- Inspections with a gradual shift in emphasis from assessing technical performance to assessing the quality of management.
- Plant modifications, which are handled through the interaction of several functional units and, therefore, can serve as an important information source.

The SKI approach is again the regulator’s initiative to establish a method for the assessment of organisational factors. The model tries to clarify how organisational factors impact on nuclear safety.

3.7 Carl Rollenhagen's model (G)

In his comprehensive work on the assessment of organisational characteristics and their influence on safety, Rollenhagen (1999) presents a conceptual framework for the assessment of human and organisational factors and their relations to risk and safety. Rollenhagen also discusses some specific assessment methods, used in the context of the Swedish nuclear industry.

Rollenhagen identifies two fundamental analytical strategies in the search for how organisational factors may influence safety. The bottom up strategy starts with the technology itself and tries to model deviations and their consequences in the technical core system.

In many of these accounts organisational factors are treated on a nonspecific basis, as “performance influencing factors” which influence the reliability of human actions. An advantage of the bottom-up strategy is that it focuses on activities and situations and maintains close contact with the technology itself. However, some important elements that also affect safety, such as “culture” and “external influences”, tend to be neglected.

With a top-down strategy Rollenhagen means a deductive mode of reasoning about organisations. Whilst this particular approach produces lists of organisational factors, however, these lists tend to lack cause-effect descriptions.

Rollenhagen tries to combine the bottom-up and the top-down strategy. He devolops a model, which should provide indicators and measures for human and organisational factors related to nuclear safety and to support organisational assessment. The model is anchored in three fundamental conceptual categories:

- *Resources*
- *Activity*
- *Technology*

The *resource concept* is used in a very general sense, as follows: A resource is anything, that can be utilised in order to conduct a human activity to reach goals. People create and use, verify and operate resources. People performing different activities are called “human resources”. This includes the individual in a holistic sense, but also includes the particular knowledge, skills and attitudes. Resources are information resources, information technology resources, human resources, time resources, financial resources and others. The resources are specified in Rollenhagen’s model in main subtypes and specific subtypes (as examples).

Activities create resource and maintain the technological states and structures. The category activity is separated from the actor (which is covered by the resources category). Activities in Rollenhagen's model are Construction/Design, Operation, Maintenance, Verification, Managing, and Analysing.

The *technological core system* comprises the hardware as it is realised in terms of components and systems.

In addition to these 3 main categories of the organisations model, Rollenhagen adds a fourth category “external influences”, where he specifies factors such as deregulation, political decisions, economic structure, and regulatory practices.

Rollenhagen does not supply specific methods for the assessment of organisational factors but using the method of event analysis at Forsmark NPP, he demonstrates, how his model could be used for organisational assessment. Using the subtypes of his main categories, Rollenhagen formulates questions for the evaluation of organisational aspects.

The development of the model is a reaction to the perceived need to establish a framework, to structure organisational factors and the need for practical models to make these more tangible. Rollenhagen's model is derived from his experience on organisational assessment. The model not only lists organisational factors, but allows statements about the interdependence of the factors to be made.

3.8 ASCOT Indicators of IAEA (H)

With the objective of maximising efforts to ensure the safety of nuclear power plants, the International Atomic Energy Agency (IAEA) invited leading experts in nuclear safety to form a working group, the International Nuclear Safety Advisory Group (INSAG). The principal aim of INSAG was to serve as a forum for exchanging international experience and to formulate common safety concepts, where possible. Publications of INSAG in the early ‘90s offered a first definition, and the suggested universal features, of a safety culture. These publications had great international resonance. It was obvious that such a broad interest indicated a need to expand on the concept of safety culture, especially because of the lack of an international consensus on the meaning of safety culture. In further publications, the concept was extended and general factors which indicate good safety culture were explored. Later on, methods and guidelines for the assessment of safety culture, the ASCOT Guidelines, were developed (IAEA, 1994). These can be used as tools to conduct organisational self-assessment in NPPs. The work of INSAG, their publications and guidelines should be seen as a significant international effort to develop a commonly-shared concept of safety culture.

The theoretical approach of INSAG is based on a definition of safety culture which is carefully composed to emphasise that safety culture consists of two major components in its manifestation: the framework created for the individual’s work and the attitude and response of individuals. “Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance” (IAEA, 1994, p.7).

The definition also expresses the view that matters, which are normally intangible (e.g. personnel attitudes, style of organisation) could lead to tangible manifestations of safety risks. INSAG also takes the view that it is necessary to consider contributions of all organisations that influence safety culture. Therefore, operational organisations, as well as governmental, research and design organisations should be involved in safety considerations. In the ASCOT guidelines, the following safety culture indicators were described:

1. Government and its organisations

- *Government commitment to safety*
- *Regulatory agencies*

2. Operating organisation

2.1 Corporate level

- *Safety policy at the corporate level*
- *Safety practices at the corporate level*

2.2 Plant level

- *Highlighting safety*
- *Definition of responsibilities*
- *Selection of managers*
- *Relation between plant management and regulators*
- *Review of safety performance*

- *Training*
- *Local practices*
- *Field supervision by management*
- *Work-load*
- *Attitudes of managers*
- *Attitudes of individuals*

3. Research organisations

- *Research input to safety analysis*

4. Design organisations

- *Codes for safety aspects of design*
- *Design review process*

Safety culture indicators as described above can be assessed by a list of questions which can be found in the ASCOT-Guidelines (1994). The method should not be seen as a checklist for yes/no answers, rather it is a guideline for organisational self-assessment that should be embedded in other methods like plant tours and documentation overviews. The Guidelines offer detailed information and time schedules for planning an ASCOT review.

The development of the ASCOT methodology of the IAEA was initiated by international resonance to INSAG 4. A need for the expansion and clarification of the safety culture - concept was obvious. The ASCOT Guidelines identify indicators of safety culture which can be used for organisational self assessment. Up to now, the ASCOT methodology has enjoyed wide international recognition and is based on broad experience.

3.9 SOL - Safety through Organizational Learning (I)

In the early ‘90s, the German regulatory authority identified a lack of applicable methods for event analysis which include human factors aspects and accordingly initiated research on event analysis. As a consequence, the Research Center Systems Safety of the Berlin University of Technology developed the SOL method, which assists the identification of organisational (Wilpert et al. 1997) factors, and which provides a method for the analysis of events in the nuclear and process industries.

SOL is based on the socio-technical systems approach (STSA), and refers to the conceptua-lization of the safety and reliability of NPP as performance outputs of the total system comprising the subsystems of technology, individual, team, organisation, and environment. Events are indicators of opportunities for system performance optimisation (Fahlbruch & Wilpert, 1997). Linked to these bases of the STSA, the understanding of events is that they result from complex interactions of systemic weaknesses, technical failures and human errors resulting in breakdowns of defence (Reason, 1990). SOL is designed to reconstruct the course of events and to find contributing factors in all 5 subsystems. As well as the factor

“Technology”, SOL proposes 18 “contributing factors”, which can be seen as organisational factors. These factors are:

- *Information*
- *Communication*
- *Working conditions*
- *Operation scheduling*
- *Violation*
- *Responsibility*
- *Control and supervision*
- *Group influence*
- *Rules*
- *Procedures and documents*
- *Qualification*
- *Training*
- *Organisation and management*
- *Feedback of experience*
- *Safety principles*
- *Quality management*
- *Maintenance*
- *Regulatory and consulting bodies*
- *Environmental influence*

A main tool for the identification of contributing factors is the SOL “identification aid”. For each organisational factor, a list of about 10 examples is given so as to clarify the meaning of the factors, which is a fundamental requirement for the application of the method.

SOL is structured in three consecutive steps: step 1 “situational description” addresses the collection and preparation of objectively available information related to the event. A graphical description of the event is drawn up through the systematic deconstruction of the event and identification of ”event-building-blocks”, containing actors and actions.

The second step operationalises the identification of contributing factors. This identification is supported by a tool called “identification aid”. The aid contains 19 contributing factors, divided into directly contributing and indirectly contributing factors. Each factor is described by its category (e.g. “Organisation and Management”), by a leading question (e.g.”Has there been an influence of organisation or management?”) and by a list of examples (e.g. “failure of employees to accept company goals, company goals not taken seriously or not represented convincingly by the management, missing resources for achieving the goals, achievement demands by the management too high, resource deficiencies for necessary improvements, absence of company regulations for improving recognised problem domains, implementation of improvements too slow”). A systematic review of these factors leads the user through the process.

The third step of SOL describes the drawing up of event reports.

SOL is designed for the use in teams of employees of nuclear power plants, who are trained in the application of the method. Workers in chemical plants, engineers from consulting organisations and human factors specialists of nuclear power plants judged SOL as an easy-to-use method, which allows the identification of organisational factors. A software tool for SOL facilitates the use of this event analysis method (Baggen et. al. 1997).

3.10 CREAM - Cognitive Reliability and Error Analysis Method (J)

The Cognitive Reliability and Error Analysis Method was developed by Hollnagel (Hollnagel, 1998). The method's goals are both the retrospective analysis of an event and the prospective forecast of an organisation's performance. Two characteristics of CREAM that are different to most of the other prominent event analysing methods are its detailed theoretical background - although mostly concentrated on cognitive aspects of human behaviour - and its well-defined stop rule for the procedure of event analysis.

No explicit theory or model of organisation is addressed yet, but there are explicit definitions of organisational factors already integrated into the method:

- Maintenance failure, e.g.equipment (controls, resources) does not function or is not available due to missing or inappropriate management.
- Inadequate quality control, e.g. lack of resources or supplies.
- Management problem, e.g. the line of command is not well defined and control of the situation may be lost.
- Design failure, e.g. the interface is inadequate, and the cause is clearly a design failure.
- Inadequate task allocation, e.g. the organisation of work is deficient due to the lack of clear rules or principles.
- Social pressure, e.g. the individual's understanding of the situation is guided or controlled by the group.

Hollnagel identified the following factors and subcategories:

Organisation

- *Maintenance failure*
- *Inadequate quality control*
- *Management problem*
- *Design failure*
- *Inadequate task allocation*
- *Social pressure*

Communication

- *Communication failure*
- *Missing information*

Training

- *Insufficient skills*
- *Insufficient knowledge*

Ambient conditions

- *Temperature*
- *Sound*
- *Humidity*
- *Illumination*

Working conditions

- *Excessive demand*
- *Inadequate work place layout*
- *Inadequate team support*
- *Irregular working hours*

No special methods are described for the assessment of organisational factors. The organisational factors are assessed like the personal and mechanical factors within the scope of the overall analysis procedure of CREAM.

The CREAM methodology addresses the need for new models in probabilistic safety assessment (PSA) which allows it to integrate organisational factors into PSA.

3.11 TOR -Technic of Operations Review (K)

The Technic of Operations Review (TOR) was conceived by Weaver (1973) as a diagnostic training and mishap prevention tool (Ferry, 1988). It follows the assumption that all organisations have operating errors that arise from underlying causes which TOR can expose. As a result, TOR identifies problem areas or weaknesses of the management. The method is not developed for a specific branch of industry. It is widely used, has been empirically tested by an insurance company, and is now copyrighted as the New TOR Analysis by the author.

In the literature it is emphasised that TOR is an empirically-developed tool for the assessment of management weaknesses (Ferry, 1988). Therefore, a theoretical basis is not given.

The organisational factors mentioned in the TOR analysis could be described as empirically proven management and supervisory factors in an operating system. TOR consists of seven factors. Each of these factors comprises in turn several examples, which could be identified as possible contributing factors to the mishap or accident. The TOR analysis consists of the following management and supervisory factors:

- *Training*
- *Decision & direction*
- *Work groups*
- *Personal traits*
- *Responsibility*

- *Supervision*
- *Control*
- *Management*

As mentioned above, TOR is not a theory or model, but a method for the analysis of mishaps or accidents whose aim is to uncover underlying causes and identify management oversights or omissions. TOR is designed for the analysis of accidents in small groups. This analysis team should consist of members of the middle management. In a first step, all information concerning the mishap are gathered and interchanged until everyone has the same level of information. Subsequent to the selection of a prime or main operational error, the analysis team can identify the contributing factors of this error by using the TOR analysis sheet. All possible contributing factors are identified, when all cross-references are taken into account. In a final discussion the identified factors are reduced to a manageable number and possible corrective actions are specified.

TOR was initiated by an insurance company to analyse accidents in industry systematically and comprehensively.

3.12 TRIPOD (L)

TRIPOD was created for the oil exploration and production operations of Shell International Petroleum by a research team from the Universities of Leiden and Manchester (Hudson et al., 1994). The project began in 1988 and was presented as the Enhanced Safety Management Program. The technique was developed in various Shell operating companies between 1989 and 1992. The revised version of TRIPOD (TRIPOD-Delta) was released in 1996.

Originally, TRIPOD was designed as a research progamme on Human Factor aspects in incidents and accidents. During the course of the project, however, a theory of accident causation was established. The instrument developed in the TRIPOD project serves as a tool for the analysis of accidents, therefore, but it can also be used as a diagnostic instrument to assess the safety standard of an organisation.

The theoretical basis of TRIPOD follows the accident causation model of Reason (1990). Accident causations are described as a chain of causes. The elements of this chain of events leading to an accident or incident are: insufficient defences, unsafe acts, psychological precursors of unsafe acts, line management deficiencies and fallible decisions. For minimising the risk of unsafe acts, the underlying mechanisms were analysed. These mechanisms were called the General Failure Types (GFT), which are close to the “latent failures” concept postulated by Reason (1990). GFT have been identified as a result of some theoretical considerations; but mainly on the basis of empirical work, e.g. a study on offshore platforms or a study of audit reports (Groeneweg 1992). The following General Failure Types (GFT) were identified:

- *Hardware defects*
- *Inappropriate design*
- *Poor maintenance management*
- *Poor operating procedure*

- *Error enforcing conditions*
- *Poor housekeeping*
- *Incompatible goals*
- *Communicational failures*
- *Organisational failures*
- *Inadequate training*
- *Inadequate defences*

As mentioned above, even though TRIPOD was designed initially as a tool for accident investigations, the need for a tool for proactive analysis of organisational structures was soon recognised and TRIPOD was therefore developed further as a method to detect organisational weaknesses and to suggest improvements.

3.13 Ontario Hydro performance assessment report (M)

Until recently, the overall performance of the Ontario Hydro Nuclear (OHN) plants was found to be well below the level of performance typically achieved by comparable plants. This was thought to be due to long standing management, process and equipment problems. These concerns led to the decision of the OHN management to perform an independent, integrated performance assessment (IIPA), which was conducted by the Nuclear Performance Advisory Group (NPAG). The IIPA was conducted over a three month period and led to an extensive report of findings and recommendations.

In the “Report to the Management” prepared for OHN, neither a theoretical basis, nor an explicit definition of organisational factors are given. The IIPA is based on seven key issues, which are further differentiated. These key issues cover all aspects of organisational factors.

Managerial Leadership

- *Employee accountability*
- *Lateral working relationships*
- *Managerial practices*
- *Support of lower level management*
- *Management oversight*

Culture and Standards

- *Culture*
- *Decision making*
- *Standards*

People and Performance

Process and Procedures

- *Performance monitoring*
- *Procedural compliance*
- *Quality assurance*
- *Work protection*
- *Root cause identification*
- *Security program*
- *Processes*

Plant (Hardware) and Design

- *Operability determinations*
- *Design documentation and change control*
- *Systems engineering and programs*
- *Safety system functional inspections results*
- *Plant status and configuration control*

Organization and Resources

- *Labour relations*
- *Assessment of collective agreement issues affecting performance.*

As methods for the assessment of these key issues, two assessment procedures are mentioned:

- The IPAP (Integrated Performance Assessment Process) methodology of the US NRC, which is described in the Inspection Procedure No. 93808.
- The INPO (Institute of Nuclear Power Operators) Performance Objectives and Criteria, described in INPO-96-006.

The Ontario Hydro approach is an example of an industry-initiated assessment of organisational factors which includes all relevant organisational aspects, e.g. incorporating upper management practices as well as lower level activities. The assessment is triggered by strong organisational performance problems and reacts to regulatory demands.

Table 1 provides an overview concerning customer activities and the needs which have been addressed by specific model developments.

Table 1: Overview of the needs addressed

#	**Model**	**Needs addressed**	**Customer**
A	NRC	Organisational Performance Assessment	US Nuclear regulatory auth.
B	Swiss	Safety culture assessment	Swiss Nuclear regul. auth.
C	OECD	Organisational factors assessment	OECD
D	HSE	Organisational performance assessment	UK Regul. Auth.
E	Finnish	Safety Culture assessment	Finnish Nuclear regul. Auth.
F	Swedish	Organisational factors assessment	Swedish Nuclear regul. Auth.
G	Rollenhagen	Framework for organisational factors	Consultant organisation
H	ASCOT	Safety Culture assessment	IAEA
I	SOL	Organisational factors and Event analysis	German regulatory auth.
J	CREAM	Organisational factors and PSA	
K	TOR	Organisational factors and event analysis	Insurance company
L	TRIPOD	Organisational factors and event analysis; Organisational factors assessment	Petro-chemical company
M	Ontario Hydro	Organisational Performance Assessment	Nuclear utility company

4. Towards a generic categorisation of organisational factors

The total sum of all organisational factors reported in the 13 models reported in chapter 3 amounted to roughly 160 different factors which are, however, highly overlapping (appendix A). In order to reduce this unwieldy number, the “meta-plan” methodology (Klebert, Schrader & Straub, 1987) was applied by a team of 25 experts in systems safety (researchers and students of the Research Center Systems Safety of the Berlin University of Technology). The meta-plan method takes the form of a structured group discussion which facilitates the visualisation and regrouping of the factors into a reduced number of general categories. As a first step each individual factor is written on a separate card (approx. 10 to 15 cm), big enough to be readable by the whole team. These cards are placed on a large board. Subsequently the cards are discussed and grouped into regions according to their similarity. After all cards have been positioned on the board, the categories of cards are considered again and, if necessary, regrouped. In a last step, a descriptive category is identified for each group.

As a result of the team process seven general categories of organisational factors were identified:

(1) Interorganisational Relations

(2) Vision, Goals & Strategies

(3) Supervision and Control

(4) Operation Management

(5) Resource Allocation

(6) Performance

(7) Technology

These categories and the factors belonging to them are shown in the table at appendix A. The table also indicates the model from which each factor was derived. Thus the table enables the interested reader to review all the factors identified from the 13 models and identify models which use the same labelling of factors.

The following offers some illustrative examples of which factors are covered by the seven general categories.

(1) Interorganisational Relations

This category relates to all extra-organisational factors, organisations or institutions which interact with nuclear power plants and which have an impact on its internal operations, such as political events, regulatory bodies, manufacturing companies, design companies and research institutions. It seems self-evident that such relations will affect organisational aspects of nuclear power plants. For instance, regulatory demands may force certain reporting and documentation activities or re-arrangements of intra-organisational responsibilities.

(2) Vision, goals and strategies

All strategic or policy objectives decided at the highest corporate or nuclear power plant level, may be placed in this category as they may relate to entrepreneurial or safety issues. These aspects must be considered important indicators of safety commitment of top management, and so aspects of organisational and safety culture find expression in this category as well.

(3) Supervision and control

In this category all those features of nuclear plants that relate to leadership and managerial functions such as employee monitoring, incentive and reward structures, definition of responsibilities, work flow coordination, training programs were assembled. The way in which such functions are conducted will undoubtedly have consequences for the internal organisational climate and trust which are the foundations staff organisational commitment and safety related activities.

(4) Operations management

All those organisational arrangements which ensure an adequate and safe work flow within nuclear plants are grouped under this heading. They cover such functions as planning, quality management, operations feedback, procedures, maintenance management, performance auditing and review.

(5) Operations performance

Specific aspects of the 'task performance' of individual staff in nuclear plants such as: work practices, violations, work protection, stress management and housekeeping were grouped under this category.

(6) Resources

Factors that enter this category consist of tangible and intangible resources from which the organisation of a nuclear plant may draw in order to guarantee safe and reliable operations. These include financial resources, information resources, labour relations, communication, staff attitudes and commitment, team spirit and staff competence.

(7) Technology

This last category covers all the technical features of the nuclear plant's hardware and software such as component quality, design and construction, defence–in-depth, physical working conditions and technical support.

It must be assumed from theory, as well as from practical experience, that the seven main categories of organisational factors described above do not operate independently of each other in impacting outcomes of nuclear power plants such as safety and reliability. In fact, complex interactions among them must be assumed. Further, it must be borne in mind that the 160 odd factors from the 13 models that were analysed were ascribed to generic categories by way of a consensus process among safety experts. One may rightly debate the adequacy of the seven categories identified as well as the validity of the grouping of individual factors within one of the seven groups. Nevertheless, it seems useful to summarise and visualise the potential interrelations among the seven categories and their influence on nuclear plant outcomes (e.g.

safety. reliability, competitiveness, profitability), as an eighth category. Such an approach is portrayed in figure 1.

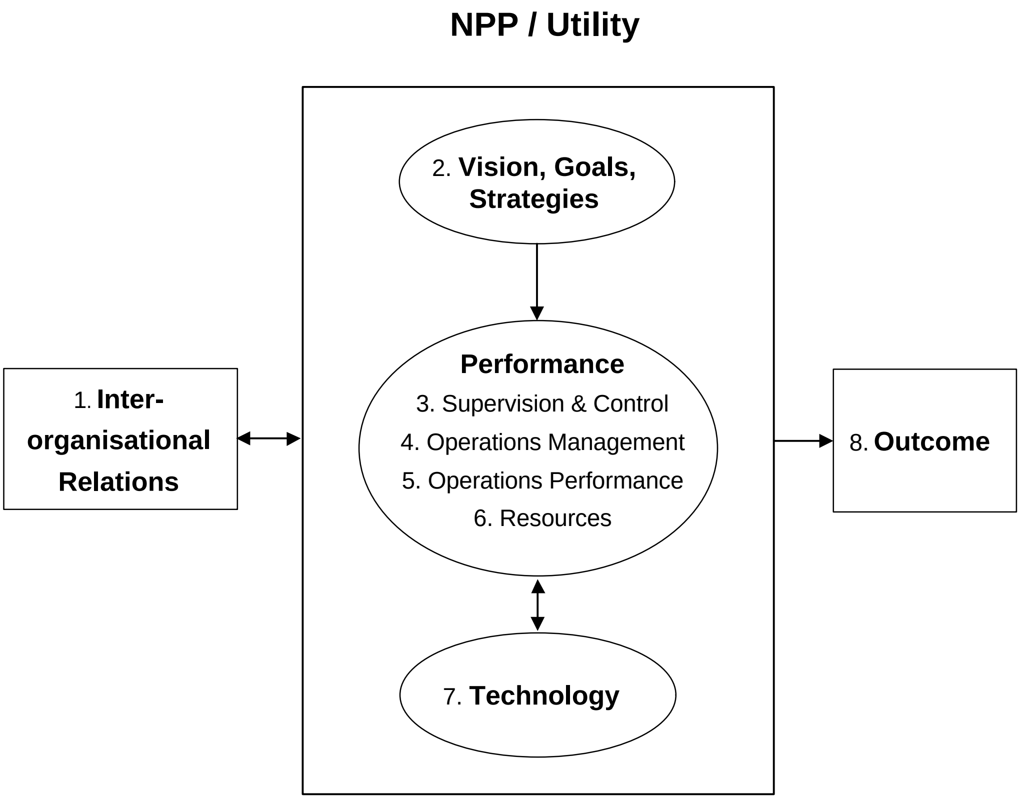

Figure 1: A generic view of ORFA

5. Towards a synthesis

In line with a decision taken during the first ORFA meeting in Espoo, October 1998, all ORFA partners and, in addition, a select group of representatives from nuclear utilities and regulating bodies were asked to present their respective views on needs and methods concerning the relevance of organisational factors in NPP. An iterative process within the ORFA team developed a set of 9 leading questions (see table 2) which were expected to stimulate thinking and evoke responses of competent experts. The purpose of the survey was to check what issues practitioners thought to be relevant when undertaking reviews of organisational factors.

Table 2: Questions concerning organisational aspects in nuclear industry

1. Do you assess the organisational performance in your plant / enterprise?
2. Do you have an explicit definition of organisational dimensions according to which you assess performance? If yes, which one?
3. When you are looking at our model of organisational factors, which categories of our model (please indicate number(s)) are covered or not covered in your assessment of organisational performance?
4. In assessing organisational performance, which categories of our model do you consider the most important ones?
5. Which methods for assessment of organisational performance do you use?
6. How have you arranged for the responsibility of the assessment?
7. Who will get the results of the assessment?
8. How are the results of your assessment used?
9. Where are the greatest needs for future research in organisational performance?

Altogether some 20 responses were obtained from utility and regulatory personnel. These were discussed in detail at the Brussels meeting in March 1999. Even when combined with the views of the ORFA partners, however, the resulting database is still too small to claim to be representative of the European perspective. However, it allows some qualitative conclusions concerning important issues which point towards areas for future work and clarification to be drawn. They are dealt with below. Responses to individual questions are not reported here. Rather, an attempt has been made to regroup these into coherent themes.

Methods in use

In view of all reactions received it is clear that a large variety of methods and approaches are used by utilities and regulators to deal with organisational aspects in NPP. A wide range of strategies, approaches and methods in use has been described in chapter 2 of this report. These methods are frequently taken from areas outside the nuclear field and are applied by managers and regulatory personnel on the basis of intuitive assumptions that they believe will lead to better understanding and control of organisational processes. Their choices seems generally to have been made with a set of implicit notions of why they are the most appropriate response to a given problem. To make these implicit notions more explicit may help to improve existing practice because it will facilitate optomised decision making and it will also demonstrate the synergetic potential of the various methods in use. However, it should be also clear that the task of making implicit models of handling organisational issues more explicit, i.e. the development of an improved theoretical understanding of them, is intellectually very challenging and time-consuming. Specific research ventures will have to address this task.

Developmental needs

An important step towards meeting the general challenge of improving the theoretical understanding of methods in use appears to be the expressed need to further develop tools for organisational assessment and process control. This need appears particularly relevant in three domains: analytical methods to assess organisational performance, proven methods of organisational intervention, and methods to integrate organisational factors in PSA.

The improvement of analytical methods for the assessment of organisational performance are called for with reference to such issues as

- how to assess the safety relevance of organisational features
- how to demonstrate the effects of certain organisational or safety cultural characteristics
- how to control the impact of organisational modifications
- how to assess the influence of organisational factors on the frequency of incidents
- how to develop standards for “good organisational practice”
- how to verify whether appropriate safety margins are in place
-

Proven methods for organisational interventions are necessary particularly in relation to issues such as-

- how to introduce, improve and maintain a “good” safety culture
- how to minimise human error through organisational change strategies
- how to optomise the allocation of resources
- how to improve human resources through personnel development
- how to transfer successfully a proven method from one national context to another

The problem of how to integrate organisational factors in the present state of the art of PSA is internationally well recognised and various research efforts seek to address this topic. However, no major breakthrough seems in sight, as yet. Additional efforts are called for in due course.

Lack of consensus regarding the nature and relevance of organisational factors

An important problem emerges due to the fact that there seems to be a lack of consensus regarding aspects of organisational factors and their relevance in the safe and reliable operation of NPP. Most practitioners will certainly agree that organisation and management are, without doubt, important factors to ensure safety. And they are often justified in their claims that a lot of work, (and some would even say, in their opinion, “enough work”), is done in that area. On the other hand, academics claim that what is done may not be enough or is often done only on the basis of haphazard guessing. Furthermore, in both camps there seems to be a certain degree of ‘disunity of opinion’ as to what ought to be addressed as relevant organisational dimensions. In fact, as some recent audits and incidents have revealed, while practitioners may rely on their implicit understanding that enough has been done with regard to organisational issues, reality teaches us a rather different lesson. Besides which, even the use of the same term may denote different things to different people. Such disagreements are easily understood in the light of the above-mentioned limited theoretical understanding and implicit handling of practical problems. This situation calls for strenuous efforts to build a better consensus among all parties.

The challenge of collective educational efforts

By way of conclusion, it is reasonable to suggest that educational efforts in the widest sense of the term are required. Such efforts will comprise increased research efforts to further clarify the various notions currently referred to as organisational factors and to further improve the methodological tools for their better assessment, as well as renewed efforts to promote some form of dialogue between practitioners and academics on the issues at hand. National, international, and governmental, as well as private initiatives, will be most important to the process of promoting such a dialogue in future.

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Appendix A: Synopsis of the content of models of organisational factors

The organisational factors which where identified on the basis of the 13 models under investigation (see chapter 3) are grouped into seven main categories. The process of grouping is described in chapter 4. The following table identifies those factors which are used in different models (A - M). The table consists of 3 main columns; Column 1 *General categories* lists the seven general categories which are the result of the process of grouping. Column 2 *Factors* contains the factors of the different models of organisational factors (chapter 3) and Column 3 *Model* refers to the 13 models of organisational factors, indicated by the letters *A - M*. An “X” in the columns indicates, from which model a factor derives. To assist the overview, identical factors are combined in one row and similar factors in one cell.

Table 3: Synopsis of the content of models of organisational factors

General Categories	**Factors**	**Model**												
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
1.Inter-organisational Relations	Environmental influence, External influences			X						X				
	Government and its organisations								X					
	Relations between plant management and regulators								X					
	Regulatory and consulting bodies								X	X				
	Research organisations								X					
	Rules and Regulations							X						
	Design organisations								X					
2.Vision, Goals & Strategies	Goals and Strategies, Goal prioritisation, Incompatible goals	X		X									X	
	Policy Safety Objectives, Safety policy at corporate level Highlighting safety Standards	 	 X 		X 			X 	 X X 					 X
	Culture, Organisational culture Safety culture	X X		X 										X
	Organisation, Organisation and management, Organsational failures				X					X	X		X	X
	Management, Manage, Managerial practices, Mgt Functions and Oversight, Mgt. problem Support of lower level management			X 				X 			X 	X 		X X
	Decisions of the corporate and plant Manag. Decision and Direction; Decision making					X 						 X		 X
	Centralisation	X												
	Industrial Safety		X											

General Categories	Factors	Model												
		A	B	C	D	E	F	G	H	I	J	K	L	M
3. Supervision and Control	Supervision, Field supervision by management Control and supervision, Control								X	X		X X		
	Rewards to the plant personnel					X								
	Definition of employee accountability, Responsibility, Definition of responsibilities, Roles and responsibilities	X							X	X		X		X
	Personnel selection Selection of managers	X							X					
	Inadequate task allocation										X			
	Coordination of work Definition of lateral working relationships	X		X										X
	Training, Inadequate traning	X	X	X					X	X	X	X		X
4. Operations Management	Analytical Methods Security programme							X						X
	Planning & Implementation, Ensuring implement. Operate				X	X		X						
	Analyse Verify							X X						
	Systematic assessment and development of safety Safety Review, Review of safety performance			X		X			X					
	Auditing and Reviewing Performance, Performance evaluation, Performance monitoring	X			X									X
	Self assessment of performance,					X								
	Quality management, quality assurance, quality control		X							X	X			X
	Organisational learning Feedback of experience Root cause identification	X		X						X				X
	Openness in uncovering and solving problems Problem identification, Problem solving process. Plant status and configuration control	X				X	X							X
	Formalisation, Proceduralisation	X		X										
	Procedures, Rules, procedures & documents, Instructions, Poor operating procedures Prodedural compliance Incomplete processes					X		X		X			X	X X
	Codes for safety aspects of design Design documentation								X					X
	Maintenance management Change control Systems engineering and programmes												X	X X
	Radiation Protection		X											

General Categories	Factors	Model												
		A	B	C	D	E	F	G	H	I	J	K	L	M
5. Operations Performance	Operation		X											
	Emergency Operations		X					X						
	Operation scheduling									X				
	Time resources, Time urgency, Work-load	X						X	X					
	Work Behavior, Work practices									X				
	Safety practices at the corporate level,								X					
	Local practices								X					
	Violation									X				
	Work protection													X
	General housekeeping, Poor housekeeping					X							X	
6. Resources	Resource Model, Resource allocation, Resources	X		X				X						
	Resources for maintenance of the high safety level, for safety relevant plant modifications					X								
	Financial resources							X						
	Other resources							X						
	Organisational knowledge	X		X										
	Information, Information resources							X		X	X			
	Collective agreement issues affecting performance													X
	Labour Relations													X
	Work groups, Group influence									X		X		
	Social pressure										X			
	Collaboration between units;		X											
	Co-operation and exchange					X								
	Communication, Communication failure	X		X						X	X	X	X	
	External communic. Interdepartmental comm.	X												
	Human Resources Management			X				X						
	Attitudes of the individuals, Attitudes, beliefs					X			X					
	Attitudes to Staff, Attitudes of managers		X						X					
	Ownership	X												
	Personal Traits											X		
	Skills, competencies, Insufficient skills										X			
	Insufficient knowledge, Qualification									X	X			
	Technical knowledge	X												
	Maintaining and upgrading professional skills					X								

General Categories	**Factors**	**Model**												
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
7. Technology	Technology							X						
	Operability determinations													X
	Technical support		X											
	Information technology resources							X						
	Safety principles									X				
	Inadequate defences												X	
	Safety system functional inspections													X
	Design failure, Inappropriate design										X		X	
	Construct							X						
	Hardware defects												X	
	Technical component									X				
	Maintain, Maintenance, Maintenance failure		X					X		X	X			
	Working conditions,									X	X			
	Error enforcing conditions												X	
	Ambient conditions: Temperature, Sound, Humidity, Illumination, Other										X			

Appendix B: Standardised safety oriented instruments concerning organizational factors

This appendix contains a set of formalised instruments that have been developed for the purposes of analysing certain safety related organisational aspects in complex socio-technical systems. These instruments are described below in standardised summary format. A more detailed analysis can be obtained from Büttner, Fahlbruch & Wilpert (1999).

The Safety Climate Questionnaire (Zohar, 1980)

Problem addressed:	Safety Climate among employees: safety perceptions of employees
Industry:	Chemical, metal, textile, food production
Method:	Standardised Interviews
Instrument:	Standardised questionnaire
Data base:	20 companies, 400 respondents
Comment:	Limited theoretical underpinnings

The Questionnaire of Employee Attitudes to Safety (Cox & Cox, 1991)

Problem addressed:	Safety culture as reflected in safety attitudes, beliefs, values of employees
Industry:	Gas production and gas transport
Method:	Postal questionnaire investigation
Instrument:	Semi standardised questionnaire
Data base:	European company, total staff involved in five countries
Comment:	Theoretical basis available, partly empirically corroborated

The EG&G Idaho Safety Norm Survey (Ostrom, Wilhelmsen & Kaplan, 1993)

Problem addressed:	Safety norms as expressions of safety culture
Industry:	Energy utilities
Method:	Postal questionnaire investigation
Instrument:	Standardised questionnaire
Data base:	More than 4,000 respondents from Energy utilities in USA
Comment:	Instrument can be used in connection with organizational development

The Safety Culture Scale (Koch, 1993)

Problem addressed:	Safety culture (attitudes and norms) in high reliability organizations
Industry:	Nuclear industry, nuclear air craft carriers
Method:	Interviews, field observation, document analysis
Instrument:	Standardised scales in questionnaire
Data base:	One nuclear plant, two nuclear air craft carriers
Comment:	Standardised instrument easy to apply, but somewhat limited in scope

Safety Attitude Questionnaire (Donald & Young, 1996)

Problem addressed:	Safety attitudes of employees
Industry:	Chemical industry, steel industry
Method:	Postal investigation, document analysis
Instrument:	Standardised questionnaire
Data base:	Several studies, 1,475 respondents
Comment:	Focus on safety attitudes of relevance for organizational change

The Questionnaire about the Safety Climate and Attitude (Cabrera & Isla, 1996)

Problem addressed:	Safety in airports
Industry:	Civil aeronautics
Method:	Postal investigation of employees and experts
Instrument:	Standardised questionnaire
Data base:	About 350 employees of airport companies and airport personnel
Comment:	Nature of methodology mainly exploratory

Questionnaire on Work Activity and Dealing with Safety (Grote & Künzler, 1996)

Problem addressed:	Evaluation of plant safety and its relationship to safety culture
Industry:	Chemical industry, transport industry
Method:	Document analysis, expert interviews, field observation, questionnaire
Instrument:	Semi-standardised questionnaire
Data Base:	More than 500 respondents from five companies
Comment:	Approach comprises technical, personal and organizational factors within a socio-technical systems framework, comprehensive

Assessing Safety Culture at a Nuclear Reprocessing Plant (Lee, 1998)

Problem addressed:	Evaluation of safety attitudes in relation to self-reports of accidents
Industry:	Nuclear reprocessing industry
Method:	Focus groups and questionnaire
Instrument:	172 item structured questionnaire
Data Base:	c. 5000 respondents
Comment:	Approach revealed differences as between gender, age, shifts/days and work areas within a socio-technical systems framework, comprehensive

Assessing Safety Culture in Nuclear Power Stations (Lee, 1999)

Problem addressed:	Evaluation of safety attitudes in relation to self-reports of accidents
Industry:	Nuclear power industry
Method:	Postal questionnaire preceded by Monthly Briefing
Instrument:	120 item structured questionnaire covering 8 domains of safety

Data Base:	683 respondents from three widely separated nuclear power stations
Comment:	Approach revealed differences as between gender, age, shifts/days and work areas within a socio-technical systems framework, comprehensive

Tool to Assess Aspects of an Organisation's Health and Safety Climate (Byrom & Corbridge, 1997)

Problem addressed:	Real-time evaluation of safety climate in conventional industries; Addresses key elements of successful safety management
Industry:	Nuclear, chemicals, engineering etc
Method:	Computer-based structured questionnaire designed for users to use themselves.
Instrument:	71 statements. Software enables users to customise survey and analyse results easily
Data Base:	16,000 respondents from 8 organisations. 400 organisations have used the tool since its launch in Jan 1998. An anonymised benchmarking service is planned
Comment:	Approach reveals real-time safety climatic differences within a socio-technical safety management systems framework, comprehensive

Tool to Assess Aspects of an Organisation's Health and Safety Climate (Mearns et al., 1998)

Problem addressed:	Evaluation of safety climate
Industry:	Offshore
Method:	postal Offshore Safety Questionnaire
Instrument:	Attitude and belief assessment questionnaire
Data Base:	722 respondents from 10 offshore installations
Comment:	Approach reveals safety climatic differences within a socio-technical framework, comprehensive

Offshore safety climate assessment toolkit (Cox & Cheyne, 1999)

Problem addressed:	Safety climate offshore organisations; Addresses key elements of successful safety management
Industry:	Offshore
Method:	Attitude, behaviour and systems assessment using questionnaire, interviews and observations
Instrument:	
Data Base:	4 offshore organisations
Comment:	Approach reveals safety climatic differences both within and between organisations