

# **ORGANISATIONAL FACTORS;**

## **Their definition and influence on nuclear safety**

### **Final Summary Report**

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## LIST OF ABBREVIATIONS AND SYMBOLS

ASCOT	Assessment of Safety Culture in Organisations Team (a programme maintained by IAEA)
ASSET	Assessment of Safety Significant Events Team (a programme maintained by IAEA)
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (Research Centre for Energy, Environment and Technology of Spain)
FSS	Berlin University of Technology, Research Center Systems Safety
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
INPO	Institute of Nuclear Power Operations
IPSN	Commissariat à l'Energie Atomique, Institut de Protection et de Sûreté Nucléaire
HSK	Hauptabteilung für Sicherheit der Kernanlagen
ORFA	The Concerted Action operated under Contract N° FI4S-CT98_0051
OSART	Operational Safety Review Team (a programme maintained by IAEA)
NPP	Nuclear Power Plant
PSA	Probabilistic Safety Analysis
R&D	Research and Development
VTT	Technical Research Centre of Finland
WANO	World Association of Nuclear Operators

## **EXECUTIVE SUMMARY**

This report contains the main results arising from the ORFA project. The objective of the project was to create a better understanding of how organisation and management factors influence nuclear safety. A key scientific objective of the project was to identify components of a theoretical framework, which would help in understanding the relationships between organisational factors and nuclear safety. The report addresses nuclear safety taking a broad perspective, which reflect and take into account the views of senior NPP management and regulators.

The project partners planned three work packages. First, a review of literature listed the identified factors and methods for assessing them. Then, a draft version of the final report was prepared to clarify the context and main issues. This draft was discussed at the ORFA seminar in Madrid 21-22 October 1999. During the seminar views and comments were collected on preliminary results of the project. Finally, this information has been integrated in the present and other reports, which will be used to give further guidance to the European Commission in the development of forthcoming research programmes in the field. The organisational factors were addressed for the first time in the Work Programme of the nuclear fission key action of the Euratom 5th Framework Programme.

Today there is an increasing recognition that safe and reliable operation of nuclear power plants (NPPs) depends not only on technical excellence, but also on individuals and the organisation. The proportion of incidents reported from NPPs with human error attributed as the direct or the major contributing cause typically appears to be about two-thirds with only one third stemming from a technical cause. A closer analysis of the human errors reveals that a large proportion could have been avoided had the organisation taken proper precautions before the incident.

The safety of nuclear power plant is built on well-established construction principles and methods for assessing safety. These have made it possible to optimise the technical systems and to reduce the proportion of incidents with a technical cause. Unfortunately there are far fewer methods for assessing the human and organisational contributions to nuclear safety.

During the last 25 years there have been considerable changes in the operating environment of NPPs and the pace of change has been increasing over the last couple of years. The deregulation of the electricity supply industry has increased economic pressures on the operators of NPPs, who have responded by downsizing their organisations and outsourcing parts of their work. Ageing plants and obsolete I&C systems are forcing NPPs to modernise, but scarcity of resources and personnel make the projects difficult to manage. Changes in the regulatory framework have also increased the burden of proof for demonstrating continuing safety. These changes are all reflected in organisational changes at NPPs. Unfortunately, however, these changes may sometimes also introduce unwanted side effects.

Several good practices for safety management have been applied at NPPs. These practices include, but are not restricted to, quality systems, incident analysis, safety committees and peer reviews. However, it is not enough just to apply a number of good practices, because the final result will always depend on how they interact.

In many NPPs there has been a decentralisation of the organisation, which has given people, increased ownership of their tasks and thereby contributed to better motivation in their work. This decentralisation has however, in some cases, created confusion within the organisation with the consequence that additional barriers for the smooth flow of information have been introduced. In the continuing development of safety management practices, it is increasingly important to assess the effectiveness of the work so as to consider alternative ways for its organisation. This can only happen if it is based on a thorough understanding of all the human and technical performance interactions within an organisational context.

There is a consensus in the nuclear industry that safety and efficiency should be built on a proactive approach where possible problems are identified and rectified before they can cause any major disturbance in operation. For technical systems the deterministic and probabilistic safety analyses have proved to be efficient tools for that purpose. The difficulty, however, is to have a similar approach that can be used in the search for, and rectification of, organisational deficiencies.

There has been a growing international interest in developing methods and tools for organisational assessments. Some of these address safety culture as the key organisational factor and propose tools for its measurement. There are also various schemes for carrying out peer reviews, which emphasise selected organisational factors. Due to the lack of a common framework for considering organisational factors, however, results that are obtained are seldom comparable and they often seem to depend more on the team carrying out the review than the organisation reviewed.

A common observation from organisational reviews is that organisational development has to be carried out from the inside, but that it may be initiated by outside triggers. It is also common for organisational deficiencies to be known in part of an organisation, but that this information does not always reach the appropriate decision-makers so that it can be acted upon. As a result of these observations, there is a need to develop methods for self-assessment and create adequate feedback loops by which the need for urgent improvements can be identified.

When considering requirements for organisational development there is a need for a balanced approach, whereby the whole and the details are considered together. This can be achieved within a systems approach. To achieve efficient safety management there is also a need for a sensible integration of the activities. The integration itself however, introduces additional dependencies in the organisation, which have to be understood and handled.

One of the conclusions from the ORFA project is that there is a benefit to be derived from making the relationships between various organisational factors more explicit. As an immediate consequence, for example, the definition of important concepts and indications of how they relate makes it easier for the organisation to stay in control. The partners in the ORFA project have concentrated, on attempting to establish a common understanding and framework for how organisations might be described and assessed. Ultimately such a framework might be used to predict the consequences of organisational change and thereby optimise organisational performance.

## **A. OBJECTIVES AND SCOPE**

The importance of the human factor in nuclear safety has demonstrated itself in several nuclear incidents and accidents. One can even claim that human errors is the single largest remaining root cause for incidents due to a continued improvement of technical systems at the operational nuclear power plants (NPPs). Causes for human errors can be found in deficient man-machine interface design, communication, procedures and training. Behind these deficiencies, however, there is often a common cause, organisation and management. The importance of organisational factors in the causal mechanisms of human error has been recognised in a number of research organisations in Europe, USA and Japan. National safety authorities have in some countries identified a need for improved understanding of organisational factors. The research efforts in the field have however been modest due to a scarcity of resources.

The main goal of the Concerted Action was to combine scattered European efforts of research in organisational factors of nuclear safety and to establish a common framework for future research in the field. The scientific objective of the project was to identify key components of an organisational theory that is practical enough to be used in assessing the state of organisational factors at operational NPPs. It was also intended to create methodologies and tools by which management at the plants could develop their own programmes for organisational development. This goal is assumed to be achieved in the exploitation of project results by the ORFA partners.

## **B. WORK PROGRAMME**

A Concerted Action within the Nuclear Fission Safety Program was carried out 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 SwedPower, Sweden. The consortium included two regulators, three research organisations one university and one utility which all have close ties to the nuclear industry. The project began in August 1998 and it was formally completed in December 1999. Reports from the project have been made available at the web-site <http://www.vtt.fi/aut/tau/projects/orfa.htm>. The project was structured around three main Work Packages, which are described below.

### **B.1 Needs and methods (WP1)**

The goal of the work package was to collect existing methods for assessing organisational factors and identifying needs for future research on this topic. FSS of the Berlin University of Technology took the responsibility for the work package. On a generic level one can identify three types of interconnected needs:

- Assessment (how well does the organisation perform, what are the most urgent problems),
- Design (what is a feasible way to structure activities, how can problems be avoided),
- Operation (how can the organisation be operated and maintained, how can organisational deficiencies be identified and corrected).

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. Sometimes methods are awaiting possible potential applications, rather than being developed for some specific purpose. Methods should be based on a theory, but many of the proposed methods do not have an underlying theory.

In the work package the partners conducted a short survey among nuclear utilities and regulators. The survey was based on an integrative model assembled from 15 models of organisational factors. Of these 13 models were investigated in larger detail (Table 1). The integrative model was based on a categorisation of organisational factors where the "meta-plan" methodology [1] was used. This methodology is used to structure a complex domain into its constituent parts. The categorisation resulted in eight general categories (cf. Figure 1) which formed the basis for the survey. Nine questions on the treatment of organisational factors were formulated and used. The ORFA partners carried out the survey in slightly different ways depending on their contacts with nuclear utilities and regulatory bodies. The conclusions of the work package are documented in the report [2].

## **B.2 Final seminar (WP2)**

The final seminar was held in Madrid 21-22 October 1999. Ciemat was selected as the host organisation of the seminar, because of its good contacts to the Spanish NPPs and the regulator. A total of 68 participants from 8 different countries and two international organisations attended the seminar. The participants represented senior management at nuclear utilities and regulators. The draft final report was distributed to all participants before the seminar. The objectives of the seminar were to:

- Open up a discussion of one of the most important remaining issues in nuclear safety,
- Share the findings of the project with nuclear utilities and regulators,
- Discuss indicators of good and bad organisational practices,
- Discuss frameworks and methods for assessing organisational performance,
- Collect feedback on the draft report,
- Define research needs in the field of organisational factors.

To attain these goals, the two days seminar was structured in two types of activities. During the first day the framework of the seminar was set by the ORFA partners, the Spanish hosts and invited presentations. On the second day, group discussions were organised in five groups, and a group reporter presented the results from the discussions in plenary session in order to draw together conclusions and recommendations. The groups were given the following questions to discuss:

- How can good and bad operational practices be identified?
- How can organisational factors be included in safety assessments?
- Which methods can be used for detecting weak signals of deteriorating performance?
- How should incidents be analysed with respect to organisational factors to give the largest learning benefit?
- How can organisational performance be collected and assessed in a systematic way?
- How can an organisation be developed in response to changes in its operational environment?
- What are the needs and priorities in further research work in organisational factors?

From the final discussion a conclusion was that, regarding the adequacy of management and organisational changes, it appears that no guarantee could be offered by a particular method, but the way to approach the problem is important and justification for the change

must be provided. In addition, it appears that managers cannot manage well if there are significant deficiencies in the institutional framework. They have to maintain balance between various responsibilities, including responsibility towards different stakeholders, and that the available job description of the managers are now perhaps deficient and a more adequate description could be missing.

The main messages coming from the seminar, which extended or reinforced the ORFA partners view, have been added in the final report. To document the exchange at the seminar, a report [3] has been produced including the slides of the presentation from the first day speakers, the content of the group discussions and the final conclusion and remarks.

The final seminar proved to be very valuable in deepening the discussion of various needs for R&D efforts in the field of organisational factors. It became obvious to many participants that research in this area has to be developed. Many of the participants in the ORFA seminar stressed the need for a pragmatic and applied approach to be adopted for possible research projects in order to reach a certain degree of maturity before more in depth theoretical work is initiated. Participants in the seminar also stressed that the goal is not to assess organisational factors, but to help the organisations to improve their work processes so as to increase safety and efficiency. That can only be achieved via close co-operation between utility personnel, regulatory people and researchers.

### **B.3 Major conclusions and final report (WP3)**

The preparation of the final report [4] demonstrated the strength of the ORFA consortium. The mix of researchers, utility people and regulators was broad enough to give an account of problems and solutions in many countries together with an in depth analysis of their strengths and weaknesses. These discussions among the partners helped in taking a more generic view on the interactions between important issues connected to organisation and management.

The final report was written in three stages. The first draft was written as a joint effort between IPSN and VTT and was based on the discussions between the partners and the results from the work package WP1. In the second stage the partners gave extensive comments to the first draft, which were integrated in the final draft and distributed to the participants of the ORFA seminar. Finally, comments, views and suggestions from the seminar were collected and integrated in the final report. The report also contains an extensive list of relevant literature. Preliminary results from the project were reported on the FISA-99 conference [5].

Among the conclusions from the ORFA project are that the ongoing changes in the whole industry are so profound that utilities and regulators alike will have to develop new skills and tools to deal with significant organisational issues. A consideration of the benefits of proposed changes has to involve also uncertainties and hidden costs. Organisational development carries an opportunity to invest in the training of plant personnel with a corresponding potential for innovations in the organisational field. It is the belief of the ORFA partners that this can be reached only through a pooling of resources and entering R&D projects, which address interactions between organisational factors and nuclear safety.

In the coming years there are many challenges facing the NPP operators. As a whole the industry is dependent on the public being satisfied that plants can be operated safely and if that trust disappears it may become politically impossible to continue operation. It is therefore



very important to avoid incidents, which could lead to extended outages and a consequent loss of public trust. Public trust can only be achieved if the industry is open and communicative.

The results, conclusions and recommendations described below are a condensation of the final report and thereby represent a common view of the ORFA partners. The participants in the final seminar also agreed with many of them, although no specific effort has been made for their validation and verification. At the final seminar specific questions were raised on the need for future research and development efforts. Many ideas were documented at the final seminar and they are briefly described below. Before an initiation of a new research project these ideas have to be discussed and refined together with managers at the participating NPPs to properly address the most urgent problems.

## **C. WORK PERFORMED AND RESULTS**

The ORFA project was initiated in response to a perceived need among the partners to open up and deepen the discussion of organisational factors and their influence on nuclear safety. All the partners were active with issues connected to organisation and management and the project was built on that body of knowledge and experience. It was also felt that there would be a benefit in exchanging views on good organisational practices in a multinational project. This was also demonstrated in discussions of observations and practices from the seven participating countries.

The common starting point for the partners was that assessment of the influence of organisational factors is very important when reviewing the safety of NPPs. This is also based on the observation that incidents and accidents often develop from small events, which are encountered in unexpected ways. Organisation and management is the most important contributing factor both for detecting and removing such hidden deficiencies in the system.

A large part of the concrete project work was connected to the establishment of a common understanding for how to approach organisational factors and their contribution to safety. This included a statement of the problem, describing and analysing major processes of change in the European nuclear industry and the approaches, which NPPs have applied in responding to changes in their boundary conditions. As a conclusion of the project the ORFA partners believe that research and development efforts can contribute to the resolution of problems which are connected to organisational factors and their influence on safety. An important result of the project was also connected to the exchange of reports and experience among the partners. The results, conclusions and recommendations from the discussions among the partners within the ORFA project are described shortly below.

### **C.1 A statement of the problem**

To convince managers at the utilities and regulatory bodies that organisational factors are important and that meaningful research work can be conducted, the final report [4] gives a brief overview of the area as a whole. The report also makes an effort to list good practices, which are in use at NPPs in Europe. A main message to the reader is that no simple cookbook solution is available and that development in organisational factors has to build on all available sources of knowledge and experience. A systems approach, which at the same time provides both an overview and details, is proposed as the main method for this endeavour.

Further work has to be based on fieldwork where real managers describe their problems and solutions.

It is difficult to treat organisational factors systematically. Firstly, it is intrinsically difficult to model an organisation, because it is a system with multiple feedback loops where everything seems to influence everything else. Secondly, it is difficult to exchange views concerning organisational factors, because concepts defined in natural language are always somewhat ambiguous. Finally the consideration of organisational factors implies that it is necessary to understand why people behave as they do. A list of organisational factors together with their definition [6] can provide some insights, but is difficult to use in the day to day management activities.

An NPP with its personnel and all written and unwritten practices is a very complex system. Therefore it is easy to make decisions which later prove to be counterproductive. If methods and tools were available which could be used to make educated predictions about how certain changes will influence safety and efficiency it would be of considerable assistance in avoiding threats to safety.

There is no ideal or perfect organisational structure, but the organisation has to be a compromise where cultures, people and technology are matched and reconciled. Organisational development, which aims at dealing with new environmental constraints and challenges, has to strike a balance between occasionally conflicting requirements.

Organisations are dynamic and they therefore have to be considered in how they respond to external and internal forces. To view the organisation as a dynamic object makes it easier to understand some of the difficulties managers have in responding to conflicting requirements. The dynamic nature of organisations provides an explanation for the fact that pursuing safety is a never-ending task.

The ORFA partners recognise that people and organisations search ways to become more efficient and that this is one of the salient features of success. The danger however, in a period of rapid change, is that the preconditions for safe operation are undermined in a search for efficiency. This can happen without prior warning and things can deteriorate for an extended period before an incident makes the deficiencies obvious. When organisational factors and their relationships are made more explicit it is easier to maintain an overview and thereby to achieve better control of safety and efficiency.

## **C.2 Nuclear, an industry at a turning point**

Considerable changes have occurred in the nuclear industry over the last 25 years. In the past, the methods applied to improve safety have tended to be mostly technical, but today there is an increased recognition that human and organisational factors also have an important contribution to make in ensuring nuclear safety.

The present deregulation of the electricity market in Europe is bringing in increasing economic constraints on nuclear plant organisations with a need for cost savings. This has led to considerable changes in many of the nuclear utilities. Unfortunately, it is easy to lose competencies, which are critical in a situation of organisational change. It is also evident that it is not sufficient to review only technical safety issues based on some approved procedure, because high reliability can be achieved only by an insightful evaluation of the whole organisation.

Organisation and management in the nuclear industry is similar to other industries, but there are also important differences. In addition to the safety requirements nuclear power has also become a highly political technology where mistakes can be extremely expensive in terms of a loss in public confidence. An accident anywhere is actually an accident everywhere. In the current situation, economics and the political context, not technology, are the greatest obstacles to the nuclear business. The earlier societal support of nuclear power has in some countries turned into a situation where even civil disobedience is tolerated as a way of expressing opposition.

### *C.2.1 Drivers of change*

One can divide the drivers into political, societal, economic and technological drivers, which interact to produce changes in the environment in which NPPs operate. The nuclear utilities in the seventies were often large state or municipality owned companies with a strong societal position. Today the companies have changed to be competitive and businesslike operating in a deregulated market. Owners and shareholders in the nuclear utilities today place greater emphasis on economic competitiveness as compared with earlier values of independence and security of energy supply. The concept of safety has also changed so that it is not seen to be associated solely with the risk of major accidents, but is also connected to the possibility of extended unplanned outages.

The nuclear utilities have responded to the changes by various adaptation processes. Sometimes the adaptation has contributed to an even more rapid pace of change. One adaptation has been to apply concepts and methods from business management in the market driven industry. To some extent this has led to a replacement of technical excellence as a driving force with concepts like efficiency, right sizing and shareholder values as new drivers.

NPPs are very complex systems, which, for safe and reliable operation, demand high levels of skill and competence in a wide range of disciplines. The complexity of the interaction between various technical systems on the one hand and between the technical systems and the human and organisational systems on the other, makes it very difficult to predict in detail what will happen in a specific situation. It is therefore very difficult to predict how a certain change will influence nuclear safety. The burden of proof that the NPPs are operated in a safe manner has at the same time been increased.

The importance of the process of organisational and management change is reinforced because many changes are occurring at a time when, because of plant ageing, upgrading and refurbishing, NPPs will need skilled and experienced people. Technical obsolescence especially in the field of instrumentation and control also creates the need for new concepts to be developed and applied at NPPs. The development of information technology and computer networks present however also new opportunities for increased safety and efficiency in the operation of NPPs.

### *C.2.2 Dangers in the process of change*

The deregulation of the electricity market has brought about extensive restructuring in ownership through privatisation, mergers and acquisitions. The restructuring of ownership may introduce problems in maintaining competency especially if shareholders perceive that there are overlaps in organisational functions.

The organisational structure has in many companies been made flatter with fewer organisational levels in a process of decentralised decision making. Decentralisation may in some cases contribute to a loss of clarity in the organisation where managers are forced to share their time with an increasing amount of administrative matters. Changing the organisational structure may break up established channels of communication and thereby create additional barriers to the smooth flow of information. The collection and refinement of information for different levels of management is sometime more difficult in a “flattened” organisation than in the old hierarchical and bureaucratic organisation.

One response to the demands for increased economic efficiency has been to outsource work. Thus, instead of retaining dedicated manpower resources for NPP sites or corporate activities, human resources are imported on an as-required, mission-oriented, basis. Such resources are often procured against a specific set of criteria; with the result that some of the issues of corporate continuity and breadth of knowledge are much less in evidence than might otherwise have been the case. The resulting narrow specialisation, lack of corporate commitment and apparent short-termism do not only have implications for the design and succession planning of any given organisation, but may also have potential implications for the successful management of safety.

When large changes occur it may be difficult to communicate the needs for change to the personnel with corresponding problems in motivation. In organisational changes there is always a period of transition between two organisational structures with a corresponding danger of confusion between old and new practices. In a rapid process of change a gap may develop between the vision that managers have of the plant and the reality on the shop floor. This gap could be the springboard for additional safety problems, which may have a domino effect on the whole organisation. During all these processes of change, it is easy to lose the margins necessary to cope with unexpected events and consequently run into a danger of unplanned and extended outages.

### *C.2.3 Responding to needs for organisational development*

From the introduction of nuclear power there has been a continuous redefinition of the components of safety. NPPs have adapted in a process of organisation learning. The most important lesson has been that safety and efficiency are not the result of a single factor or programme, but instead depends on all activities.

In the past the nuclear industry was exceptional in its willingness to share best practices. This has clearly contributed to the generally good results obtained by the industry. This situation may change, however, against a backdrop of increased competition between the electric utilities and may hamper the feedback of operational experience if not vigorously prevented by the highest management of the nuclear utilities.

In a changing environment, where a great many constraints are imposed on the organisation there are increased possibilities for emerging organisational deficiencies which should be detected as early, and as effectively, as possible. There is a clear recognition that organisational factors have to be taken into account, but considerations have often been implicit and actions performed in an intuitive manner.

In the future organisations are likely to need an improved overview of how they work. This may require new tools for describing work processes in order to show the coherence of safety management throughout a plant’s activities. A balanced approach also implies that the

whole enterprise and its detailed activities are considered at the same time with a reasonable integration of various component activities. There has been a growing international interest in developing methods and tools for organisational assessments and for collecting indicators of organisational performance. Some of these address safety culture as the key organisational factor and propose tools for its measurement.

#### *C.2.4 A regulatory perspective*

The regulatory climate of nuclear power has also changed. In the pioneering days regulation was created almost in parallel with plant concepts. Early regulation was technical in its content, but today regulators are also stressing the quality of work in safety related work processes. Requirements concerning human and organisational factors are now moving into the regulatory regime. The result of these changes is that the burden of proof that the NPPs are operated in a safe manner has been increased.

The processes of change that the nuclear industry has experienced so far and the responses to the changed environment have forced regulators to acquire an enhanced understanding of human and organisational factors. With the increased understanding of these human, organisational and management influences on nuclear safety, some regulators have expressed a growing concern that the overall safety of some NPPs may actually be decreasing.

Licensees and regulators hold a view that efficient regulation is fostered in an atmosphere of co-operation and mutual respect alike in many countries in Europe. Requirements in the field of organisation and management have to be examined very carefully so as not to create more problems than are solved. Effective regulation and inspection relies on good communication between people and on mutual respect and understanding. If inspections are not considered fair, or produce objections, which are considered unfounded or unreasonable, an atmosphere of mutual trust can easily be destroyed.

Whilst clearly having merit in some circumstances, the creation of a highly prescriptive regulatory approach to the examination of organisation and management issues might not prove to be a completely satisfactory approach for all NPPs in all circumstances.

Safety culture has become an important concept in regulatory practices, but the concept is difficult to define accurately in a technical sense. Regulatory pressure on NPP operators to show that their safety culture is good can therefore cause confusion if the process is not progressed in a logical, incremental fashion.

### **C.3 Organisational assessment and development**

Organisational adaptation and learning is based on consecutive efforts of assessment and development. Observed performance is compared with targets and reasons for deviations are investigated to generate actions for improvements. The high safety requirements in the nuclear industry, however, make it necessary to consider not only a result as seen by various indicators, but also the work processes and their efficiency.

In the management of organisations one can identify three basic interlinked needs. Firstly, it is necessary to understand what the important characteristics of organisations are and how they interact. Secondly this understanding has to be applied to predict, how certain actions are likely to influence organisational performance. Thirdly it is necessary to detect

early signals of deteriorating performance to initiate corrective actions before an incident is making the deficiencies obvious. Efficient responses to these needs have to rely on an integrated view of the organisation and various manager roles.

The nuclear industry has instituted several practices, by which the present high safety level has been achieved. To support an understanding of organisational characteristics and an exchange of operational experience between different organisational settings agreed methods to describe organisations are needed. Assessments of organisational performance should aim for objectivity, which however is difficult to achieve. Exchange of good organisational principles between very different organisations can be achieved only at a relatively generic level, because it is difficult to account for the influence of organisational culture.

### *C.3.1 Safety management in practice*

Nuclear power plant operators have understood the impact that organisation and management can have on performance. Many strategies and practices are therefore used in which organisational factors are relevant. NPPs have a formal organisational structure, with authority and responsibilities described in organisational handbooks. 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 towards a matrix approach whereby tasks cut across several lines within the organisation.

NPPs, 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 to 5-year forward strategic outlook, which is converted to annual plans. These in turn, form the basis for budgeting and resource allocation.

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 an agreed definition of quality and a description of the procedure needed to attain the specified level of quality.

Many European nuclear power plants have formed *safety committees* to support their senior management. The mission, organisational placement and composition of the safety committee varies, but they are generally similar. The role of the safety committee is to advise on various safety issues and they often approve incident reports, PSAs, audit reports, plant modifications, safety cases, etc.

NPPs have systems for *analysing incidents* occurring at their plants. The methods vary, but they are very similar in application. The methods are good at detecting technical problems, but they are not as efficient in identifying human or organisational causes. Most NPPs have been involved in *peer reviews*. A peer review is carried out in a similar way to a quality audit, but the scope of the assessment is broader. *Performance appraisals* are used at many nuclear power plants as a systematic tool to assess performance and set personal goals.

### *C.3.2 Understanding organisations*

The organisation of a NPP can be thought of as a control system, which ensures that activities and work processes are carried out efficiently and with sufficient quality. One task of management is to maintain this control system functional which means that feedback on its performance has to be used for initiating corrective actions. To help the management in this

task there is a benefit of using agreed ways to describe different parts of the organisation and their interactions. The line organisation is typically used to define a line of authority and channels of reporting.

In trying to understand how organisations operate it is necessary to separate the described formal organisation and the actual way the organisation carries out its work. A common observation from many organisations is that there can sometimes be a considerable discrepancy between the as described and the real organisation. Keeping described and actual work practices in line requires a continual effort. By describing organisations in greater detail there is a benefit in identifying certain key concepts through which interactions are mediated. Such concepts suggest workflow analyses to make it possible to understand and describe how the organisation operates in various tasks.

Work processes are sometimes considered complementary to the line organisation. The work processes provide a dynamic and horizontal view and the line organisation as described in the organisational chart a vertical view of the organisation. Considering work processes at a NPP there are many different ways to define and structure them. Some work processes are directly connected to the NPP itself and others to creating and maintaining resources used by the main processes. There is often a need to build models of the work processes so as to be able to assess formally how they interact. The report [7] gives some suggestions for how this can be done.

### *C.3.3 Methods for organisational assessments*

Organisational assessments aim for the detection of hidden problems, which may need urgent action for their correction. The problem is that processes of deterioration can be very subtle and that corrective actions may face resistance. Already sensitising managers for common indicators of emerging problems can provide important help in avoiding various pitfalls.

From the experience shared in the ORFA group, it is possible to carry out organisational assessments in which links between organisational factors are evaluated from different points of view. In approaching organisational problems it is necessary to identify key variables and to select a framework within which the problem can be defined and solved. Sometimes it is necessary to combine methods or even create new ones.

One difficulty in organisational assessments is that they usually rely on observations and interviews. For a method to be reliable and valid the results should not depend on the persons doing the assessment. This requirement is hard to meet, because signals of deteriorating performance may be hard to see and the assessor may have certain prejudices. The methods have also to be based on mutual trust between the assessor and those assessed that recommendations will be to the point and fairly treated.

Methods for self-assessment could make organisations more sensitive to any intentional and unintentional consequences of organisational change. Various organisational factors and their links with safety have to be examined in order to assess the efficiency of the work and to consider alternative ways for an organisation. Making the organisational elements of performance more explicit can also provide people at the plants with concepts for an internal evaluation. This would support a proactive approach in which possible problems are identified and rectified before they have caused any major disturbance in operation.

Some organisational assessment methods focus on events. Events reveal certain aspects of how the organisation is functioning. Some organisational factors, explain the causes of the events whilst others explain the recovery process. A non-blaming culture in the analysis of incidents is necessary to achieve an unbiased investigation of the root causes involved. This culture also gives people the opportunity to recognise errors and to achieve a rapid recovery.

Descriptions of the organisation and its work processes can serve as a development tool for managers. Mapping the main features of safety management in a routine manner can make managers better aware of their organisation. Efficient management relies both on insight and a systematic use of methods and tools. A systems approach, which supports a consideration of both the whole and the detail, is often helpful in this connection.

#### *C.3.4 Good organisational principles*

Organisational assessments, peer reviews and research studies have identified many good organisational principles for increased safety and efficiency. It is however not an easy task to determine to what extent such principles are generic or apply only to some local conditions. Sharing good organisational principles over company and national borders is not an easy task, but a better understanding of interactions between various organisational factors can facilitate it.

There is a consensus that high reliability organisations have to rely on an organisational structure with clear lines of responsibility and authority. There is also agreement that the authority to make decisions should be placed at the level where all necessary information is available. A good principle in an organisation with requirements for a very high reliability is to give the most junior person the authority to challenge the basis for judgement and to require a safety first approach to operation.

An organisation has to protect itself and its members from over-confidence. This attitude has to rely on a moral code and ways need to be found to make this code explicit. A moral code can in a way be seen as a contract in which the organisation and personnel undertake certain obligations.

People in any organisation are strongly influenced by and are very responsive to perceived expectations from the top management. This makes it very important for senior managers to obtain feedback on how their statements and messages are interpreted by people in the organisation. Participation in audits and peer reviews has the potential of bringing in a better understanding of own work practices.

Organisations have to find the right balance with respect to several dilemmas. Among these are the balance between procedure and knowledge, organisational and individual responsibility, centralisation and decentralisation of decision-making, etc. There are insights to be gained by an increased benchmarking of good practices.

#### *C.3.5 Organisational culture*

Organisational culture is one of the most important factors to be considered when assessing organisational and managerial solutions. Organisational culture is both influenced by and influencing selected practices and interpretations of internal and external events. Unfortunately, however, organisational culture is not easy to define or measure, because it is



related to the system of shared assumptions and meanings, which permit people to interact efficiently in various tasks.

Organisational deficiencies can sometimes be attributed to an organisational culture that is not suited to the mission of the organisation. The question is then how that culture could be changed to a more suitable one. In applying the concept of organisational culture it is important to note that only seldom is a single culture involved, but instead a mix of different cultures which are connected to education and training, job categories and local communities as well as to companies, regions and countries.

The extent to which the concept of organisational culture is beneficial for an analysis of organisational performance depends very much on the context. Still it is also necessary to understand that the existing organisational cultural context may influence the efficiency of organisational practices. Discussions between the ORFA partners and participants in the final seminar clearly demonstrated the benefit of challenging specific practises as a way to open up a discussion of deeper assumptions and meaning.

The extent to which national cultures have to be reflected in management and organisational structures is not clear. It is however evident that a simple transfer of foreign organisational solutions and practices is not necessarily appropriate without an adaptation process. Such an adaptation process can be more or less conscious, but it has to consider what people find meaningful and how they engage in work activities. It has also to adapt to the power structures found in the organisation and between the organisations, which co-operate in the operation of the nuclear power plants.

Safety culture is closely related to organisational culture and an organisation, which is permeated by a concern for safety, is often seen as having a good safety culture [8]. This is also based on a national culture, which has been conveyed through societal norms, the educational system and the business environment in the country. These issues are becoming increasingly important, because companies are splitting up and merging at an increasingly rapid rate. It is important to understand the cultural background and its influence to achieve an efficient exchange of operational experience.

### *C.3.6 Challenges for the future*

A proper combination of the three basic needs of the introductory paragraph projected towards the future suggest a list of major challenges for the nuclear industry in Europe. Changes within the industry are expected to continue far into the next millennium. Competition will maintain the need to identify further cost reductions and rationalisation of work processes. Deregulation will continue and acquisitions and mergers will remain among the responses of the industry. One may even paint a picture of an industry that in the future is operating far more globally. In entering such a development there are opportunities and challenges, but there are also many new dangers. To maintain credibility the nuclear industry has to avoid discontinuities, which implies the selection of an evolutionary strategy. This means that the nuclear industry cannot jump at the latest management whim, which has a promise of increased cost efficiency.

A serious accident at a nuclear facility in Europe will have devastating effects on the whole industry, but even minor events may have a large impact if they are linked to fraud and misconduct. The industry as a whole is dependent on the public being convinced that plants are operated safely and if that trust disappears it may become politically impossible to

continue operation. Public trust can only be achieved if the industry is open and communicative. Such an atmosphere is also supportive for nuclear safety, because it fosters organisational learning.

A major challenge for the NPP operators will be to maintain the knowledge and skills needed to operate plants safely and efficiently. This may become increasingly difficult, because the nuclear community is presently fighting with increasing problems in attracting young and talented persons who are willing to commit themselves to a career in nuclear power. This problem will also make it more difficult to find managers for various positions in the utilities and at the regulatory bodies. Nuclear operators may in the future be forced to pool their resources to maintain critical but expensive competency.

In the process of change many sometimes competing goals have to be balanced in such a way that an overview is maintained at the same time as all details are handled with a sufficient accuracy. This can be done only with an understanding of the components of organisation and management and their contribution to continued safety and efficiency. A final challenge is to find organisational structures, which motivate people, because safety has to rely on systems, but the systems cannot function without individuals.

#### **C.4 Research needs**

Needs for research and development were identified both in the discussions between the ORFA partners and at the final seminar. It is a conclusion from the project that addressing these needs will form an important part of the survival strategy for the nuclear industry.

R&D can serve short and long term needs. Among the short-term needs the following were identified:

- methods and tools to describe organisational structure and the management of work practices,
- an identification and exchange of good practices in response to rapidly changing environmental conditions of the nuclear power industry,
- identification of reasons for resistance to change and other obstacles to organisational learning,
- improved methods for the inclusion of organisational factors in incident analysis,
- methods to support succession planning and the maintenance of corporate knowledge,
- inventory and development of methods and tools for organisational self-assessments,
- comparison of safety management practices and the creation of guidance for the development of regulatory practices,
- differential use of Total Quality approaches in European NPPs and their ways of handling safety issues.

This research is related to the generic problems of managing change in an organisation. In approaching the European nuclear industry with proposed research projects, it is necessary to recognise that there are differences in national and company cultures, ways to organise, work practices and business environments. One approach for seeking answers to burning questions in short-term research is to make a collection of case studies of plant or company changes.

Among the long-term research needs the following were identified:

- development of theoretical models for the interaction between organisational factors and safety performance,
- development of proactive methods of organisational design,
- development of methods for the integration of organisational factors in PSA-models,
- development of the understanding of the potential impact of cultural influences in the safety management of the plant and in the relationship between plants and regulators.

The research needs above are listed without any assignment of priority, because specific needs will vary between companies and countries. It is also assumed the needs will require regrouping and reformulation in co-operation with the NPPs entering the work. The ORFA partners will also in their exploitation of project results make that prioritisation based on the more specific needs as seen in their own national systems.

The research efforts should concentrate on real cases of organisational change in nuclear plants or companies. It would be beneficial to collect data in a format to support a systematic inter-comparison of important issues. Case studies should be summarised with an account of lessons learned in the use of methods and tools. Finally, it is important to document generic findings in a form to make them accessible across national and company cultures.

The research has to be interdisciplinary to allow an integration of technical expertise with psychology, sociology, management science and anthropology. The research has to be based on openness and trust among the partners involved in the work. The partners should also perceive the work as important with a feeling that correct priorities are given to different issues of interest.

Many new questions were formulated both in the project and during the final seminar. These can also be seen as a proof that the consideration of organisational factors can provide a useful input to nuclear safety.

## **CONCLUSION**

There is a clear consensus among managers both at utilities and within regulatory bodies that organisational factors are important components in nuclear safety. It is also likely that they will become increasingly important in the future. There has been public concern that problems associated with the human factors nullify any attempt to ensure nuclear safety. In countering such arguments there is a need to open up the discussion on organisational factors so that the public can see that issues are being dealt with in a responsible and prudent manner.

All agree that organisational factors make a difference, but there is no consensus on which factors are the most important. Certain aspects of organisational factors and their relevance to the safe and reliable operation of NPPs are disputed, although most practitioners agree that organisation and management are important factors to ensure safety. What is done may not be enough or is often done without a proven approach. Recent audits and incidents however seem to reinforce the point that the implicit assumption that enough has been done with regard to organisational issues can be incorrect. Furthermore, there seems to be a lack of consensus as to what ought to be addressed as relevant organisational dimensions. This situation calls for strenuous efforts to build a better consensus among all parties.

Further, there seems to be a need for educational efforts in the widest sense. This calls for a multi-disciplinary effort to combine models and methods from behavioural and

management sciences for a wider application in the field of nuclear power. Such efforts will comprise increased research efforts to further clarify the various concepts currently referred to as organisational factors and to further improve the methodological tools for their better assessment. Renewed efforts will also be needed to promote some form of dialogue between practitioners and researchers 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.

Common and efficient components of methods for organisational surveys should be identified, generalised and made available within the nuclear industry. In such a development, the role of the regulator and the practices for interacting with the utilities could be clarified. Regulatory bodies need to have a good understanding of the work processes and methods the utilities are using so they can adopt the most appropriate regulatory strategy. Such a common understanding can be reached only through a three party co-operation between utilities, regulators and research. As a result of the ORFA project it is felt that the time is ripe for sharing practical experience from the assessment of organisational factors in the form of case studies for a development and validation of methods and tools for organisational assessments.

## REFERENCES

- [1] Klebert, K., Schrader, E. & Straub, W. G. (1987): *KurzModeration: Anwendung der ModerationsMethode in Betrieb, Schule und Hochschule, Kirche und Politik*. Hamburg: Windmühle.
- [2] Bernhard Wilpert, Rainer Miller, Björn Wahlström (1999): *Report on Needs and Methods*, AMM-ORFA(99)-R03, May.
- [3] Björn Wahlström, Jari Kettunen, Pekka Pyy (Eds.) (1999): *Proceedings from the ORFA seminar in Madrid 21-22 October 1999*, AMM-ORFA(99)-R05, December.
- [4] Geneviève Baumont, Björn Wahlström, Rosario Solá, Jeremy Williams, Albert Frischknecht, Bernhard Wilpert, Carl Rollenhagen (2000): *Organisational Factors; their definition and influence on nuclear safety*, Final Report, AMM-ORFA(99)-R06, January.
- [5] Björn Wahlström, Rosario Solá, Albert Frischknecht, Geneviève Baumont, Bernhard Wilpert, Carl Rollenhagen (1999): *Organisational factors; their definition and influence on nuclear safety*, FISA 99 - EU Research in Reactor Safety, 29 Nov.-1 Dec.
- [6] OECD/NEA (1999). *Identification and Assessment of Organisational Factors related to the Safety of NPPs*, NEA/CSNI/R(98)17, Volume 1 & Volume 2, State-of-the-Art Report - February.
- [7] Carl Rollenhagen (1999). *A framework for assessment of organisational characteristics and their influences on safety*, AMM-ORFA(99)-R02, May.
- [8] IAEA (1991) *Safety Culture*, a report by the International Nuclear Safety Advisory Group, IAEA Safety Series No. 75-INSAG-4.
- [9] Jacobs, R. & Haber, S. (1994). *Organizational processes and nuclear power plant safety*. *Reliability Engineering and System Safety*, 45, 75-93.

- [10] KSA (1994). Safety culture in a nuclear installation - reflections on its assessment and promotion (Eidgenössische Kommission für die Sicherheit von Kernanlagen KSA /75 E). Würenlingen.
- [11] Hurst, N.W., Bellamy, L.J. & Geyer, T.A.W. (1990). Organisational, Management and Human Factors in Quantified Risk Assessment. A Theoretical and Empirical Basis for Modification of Risk Estimates. In M.H. Walter and R.F. Cox (eds.), Proceedings of the Safety and Reliability Society Symposium, 1990, 19-20 September 1990, Altrincham. (pp. 70-79). London: Elsevier.
- [12] Laaksonen, J., Ojanen, M. & L. Reiman (1996). Safety culture - the Finnish approach. Unpublished Paper.
- [13] Dahlgren, K. & Olson, J. (1994). Organizational factors and nuclear power plant safety: A process oriented approach. PSAM-2, San Diego, CA, 1994.
- [14] IAEA (1994). ASCOT Guidelines (IAEA- TECDOC-743). Vienna: International Atomic Energy Agency.
- [15] Wilpert, B., Maimer, H., Miller, R., Fahlbruch, B., Baggen, R., Gans, A., Leiber, I., Szameitat, S. & Becker, G. (1997). Umsetzung und Erprobung von Vorschlägen zur Einbeziehung von Human Factors (HF) bei der Meldung und Ursachenanalyse in Kernkraftwerken (BMU-1998-505). Bonn: Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit.
- [16] Hollnagel, E. (1998). Cognitive reliability and error analysis method, CREAM. Oxford: Elsevier.
- [17] Weaver, D.A. (1973). TOR analysis. A diagnostic training tool. ASSE Journal, June 1973(pp. 14-29).
- [18] Hudson, P.T.W., Wagenaar, W. A. & Reason, J.T. (1989). Human error and safety management. Reader for the workshop of safety management.
- [19] Report to the Management IIPA/SSFI Evaluation Findings and Recommendations (1997). <http://www.hydro.on.ca/OHNewSit.nsf/Public/ConsInfoNewsIIPAReport>.

## TABLES

Table I: Models of organisational factors assessed in the ORFA project.

<ol style="list-style-type: none"><li>1. NRC model of organisational factors [9],</li><li>2. Swiss Federal Nuclear Safety Commission [10],</li><li>3. OECD/NEA Principal Working Group No. 1, Task 7 [6],</li><li>4. HSE Health and Safety Management [11],</li><li>5. Finnish Safety Evaluation Memorandum [12],</li><li>6. Swedish “Factors to Promote Continuous Improvement Organisations” [13],</li><li>7. Carl Rollenhagen's model [7],</li><li>8. ASCOT Indicators of IAEA [14],</li><li>9. SOL - Safety through Organizational Learning [15],</li><li>10. CREAM - Cognitive Reliability and Error Analysis Method [16],</li><li>11. TOR -Technic of Operations Review [17],</li><li>12. TRIPOD [18],</li><li>13. Ontario Hydro performance assessment report [19],</li></ol>
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## FIGURES

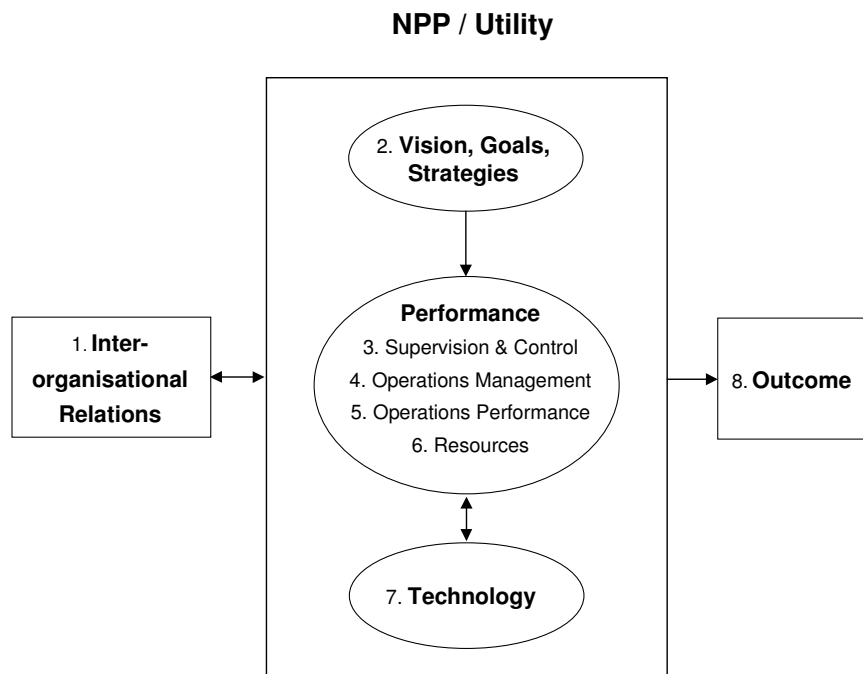


Figure 1. A generic view of ORFA