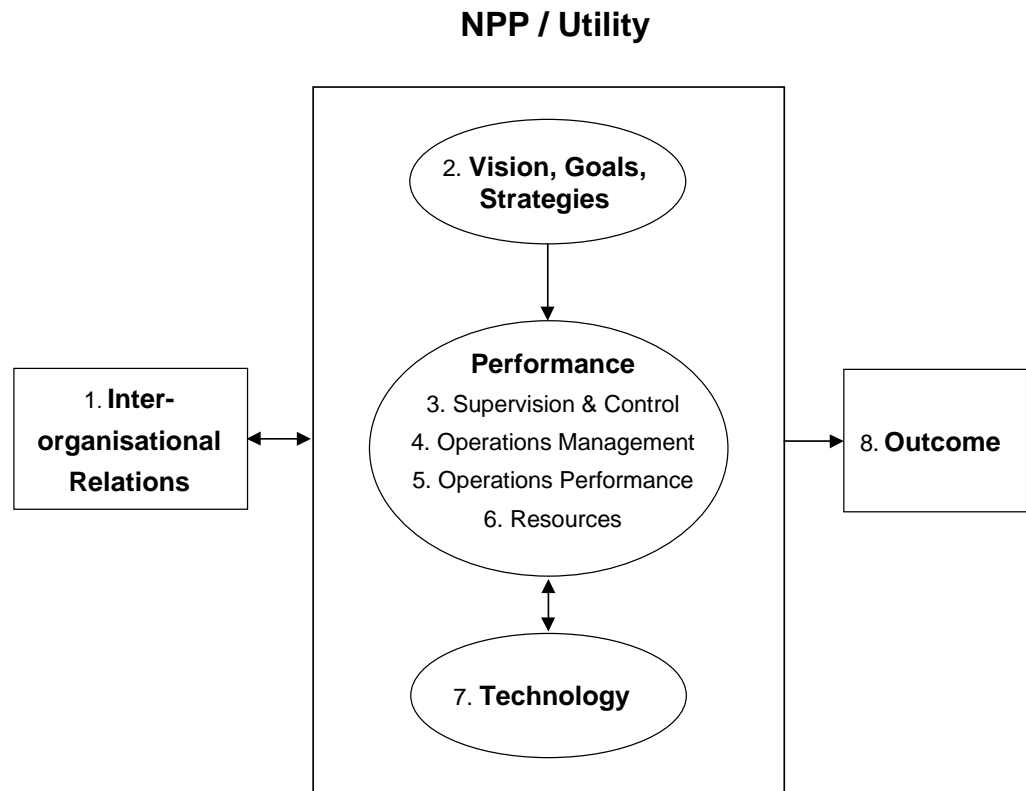Geneviève Baumont, Björn Wahlström,
Rosario Solá, Jeremy Williams, Albert Frischknecht,
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Organisational factors
Their definition and influence on nuclear safety
Final report

NPP / Utility

ORGANISATIONAL FACTORS

Their definition and influence on nuclear safety
Final report
CONTRACT No. ERB FI4S-CT98_0051

Geneviève Baumont

IPSN, France

Björn Wahlström

VTT Automation, Finland

Rosario Solá

Ciemat, Spain

Jeremy Williams

Nuclear Safety Directorate, United Kingdom

Albert Frischknecht

HSK, Switzerland

Bernhard Wilpert

Berlin University of Technology, Germany

Carl Rollenhagen

SwedPower, Sweden

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This report was prepared as an account of work sponsored by the European Commission. The report has been prepared by seven individuals from seven organisations. Because the report has not gone through a formal review process the thoughts and opinions expressed do not necessarily reflect the opinion of either the European Commission or the participating institutions.

Abstract

The importance of organisational factors in the operational safety and efficiency of nuclear power plants (NPP) has been recognised by many organisations around the world. Despite this recognition, however, there are as yet very few methods by which organisational factors can be systematically assessed and improved. The majority of research efforts applied so far have tended to be modest and scattered. The ORFA project was created as a remedy to these problems.

The objective of the project is to create a better understanding of how organisation and management factors influence nuclear safety. A key scientific objective of the project is to identify components of a theoretical framework, which would help in understanding the relationships between organisational factors and nuclear safety.

Three work packages were planned. First, a review of literature listed out the identified factors and methods for assessing them. Then, a draft version of the present report was prepared to clarify the environment context and the main issues of the topics. 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 and will be used to give further guidance to the European Commission in the development of forthcoming research programmes in the field. The project has addressed nuclear safety taking a broad perspective, which reflected and took into account the views of senior NPP management and regulators.

The questions discussed during the project have been:

– how can organisational factors be included in safety assessments,

– how can good and bad operational practices be identified,

– 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 data on 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 for further research work in organisational factors?

Contents

Executive summary

This report contains the main results arising from the ORFA[1] 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 concerted action partners planned three work packages. First, a review of literature listed the identified factors and

> *Research efforts in organisational factors have been modest and scattered.*

methods for assessing them. Then, a draft version of the present report was prepared to clarify the environment context and the main issues of the topics. 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 and will be used to give further guidance to the European Commission in the development of forthcoming research programmes in the field; this topic is addressed for the first time in a line of the nuclear fission part of the 5th Framework Programme.

The main result of the ORFA group is to provide clarification of the European context. 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

> *Safety depends not only on the technical systems, but also on people and organisation.*

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.

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[1] ORFA "Organisational Factors; their definition and influence on nuclear safety" is a Concerted Action within the Nuclear Fission Safety Programme which is running under the Contract N° ERB FI4S-CT98_0051 of the European Union between the seven partners VTT Automation, Finland, CIEMAT, Spain, Nuclear Safety Directorate, United Kingdom, HSK, Switzerland, IPSN France, Berlin University of Technology, Germany and SwedPower Ltd, Sweden.

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.

> *There has been a considerable change in the societal environment for NPPs.*
>
> *Deregulation is placing increasing economic pressures on NPP operators.*

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.

> *Safety and efficiency relies on a proactive approach.*

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 to proceed. 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 need to be pursued and that this 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

> *There is a need for better methods and tools for organisational assessment and development.*

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. There is a need to compare different methods and some iteration seems necessary as between theory and practice to reach a consensus on how organisational assessments should be carried out.

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

> *Organisations have to improve from the inside, but improvements are possible only if needs are recognised.*

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 the most urgent improvements can be identified.

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

One of the main assumptions in 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. Basically what is needed now is an organisational theory that will take this development process forward. Unfortunately, however, this is an overly ambitious goal for a project, which is restricted in resources and time. The partners in the ORFA project have concentrated, therefore, 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.

1. Introduction

The ORFA project was initiated in response to a perceived need among the partners to open up and deepen the discussion of organisation and management and their influence on nuclear safety. All the partners were active in the field of organisational factors 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.

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 was 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.

For the nuclear industry it is very important to avoid incidents which could lead to extended outages and a consequent loss of public trust. The industry today is facing an increasingly rapid change of the environmental conditions in which it operates and it is therefore trying to adapt to these changes in its organisational development processes.

The ORFA partners recognise that people and organisations always 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. A common question asked by many regulators today is the extent to which decision-makers in the nuclear industry consider safety aspects when profound changes are introduced in the organisational structure and in crucial work practices. In a period of a search for increased efficiency, it is useful to remember the statement of an Ontario Hydro manager "If you pursue safety, you get efficiency, if you pursue efficiency, you get an accident".

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 also 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. It is not sufficient that crucial work processes are carried out correctly once or twice, but they have to be performed with the same quality from year to year irrespective of the fact that people leave and new people join the organisation.

A second observation is that a 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. The unavailability of suitable predictive tools for organisational design means that NPP organisations have considerable difficulties living up to their objective of having a proactive approach to safety.

Finally it is obvious that 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. Theories and models have been developed to make various aspects of organisation and management easier to comprehend. Ideally the models should help in structuring the problems and setting priorities, but due to communication a gap practitioners often see models as unnecessary exercises.

In an organisation, which is faced with large changes, the main question is to find viable strategies for their smooth implementation, without introducing new and more complex problems. A simplistic answer to this question is that the organisation should use its human resources to:

− capitalise technical and safety knowledge and to communicate it efficiently within the organisation,

− build in barriers on several levels which have the capability to catch and correct human errors in various activities and if they occur limit their consequences,

− consider the NPP and its people as a system and search for deficiencies, which have the potential to combine in unexpected ways and thus act as a trigger for an unwanted course of events.

All ORFA partners recognise the difficulty in treating systematically organisational factors. 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. That means that linear explanations of relationships, which are based on a cause-consequence rationale, are difficult to use.

Secondly, it is difficult to exchange views concerning organisational factors, because concepts are defined in natural language. People often interpret the same word in

different ways and it is thus difficult to reach a common understanding what some statement means. People and organisations are also very different, so interpretations are influenced by the national, company and plant cultures.

People and organisations change with time and so do words and concepts. Words are often used in a metaphoric or allegorical sense. All these problems are further aggravated by the fact that no commonly accepted measuring methods for assessing organisational performance is available.

Finally the consideration of organisational factors implies that it is necessary to understand why people behave as they do, how motivation and intent is formed, etc. One specific problem in studying organisational factors is that people seldom like outsiders to tell them how to do their job. If problems are detected in an organisation change processes have to be carried out from the inside even though an outside trigger may have initiated the process. If a change is necessary in an organisation it will need the support of people in order not to create resistance to even urgently needed changes.

The ORFA partners have shared their experience, their views and the results of earlier projects in their discussions. An aim of the ORFA project was also to share views and findings within the nuclear community in Europe. An efficient way to achieve this and to obtain initial feedback from practitioners was to arrange a seminar where the issues were discussed. The seminar was held in Madrid 21–22 October 1999 where a draft of the final report was presented and discussed in the light of experiences presented in a number of invited papers. The present report builds on the draft presented and the views expressed at the seminar. The report focuses mainly on the European situation with an emphasis on the drivers of change.

To convince managers at the utilities and regulatory bodies that organisational factors are important and that meaningful research work can be conducted, the report gives a brief overview of the area as a whole. The report also makes an effort to list some of the 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. Finally any efforts have to be able to respond to the most urgent questions, but to do it in such a way that long-term problems are also tackled.

2. Nuclear, an industry at a turning point

2.1 The nuclear industry in Europe and in the world

Considerable changes have occurred in the nuclear industry over the last 25 years. In the mid seventies new nuclear power plants (NPP) were built at an accelerating pace. Today there is considerable opposition to nuclear power in many countries. Nuclear power in Europe has made an important contribution to the generation of electricity, which would be difficult to replace without considerable impact upon the environment.

During the last 25 years two devastating accidents initiated a thorough re-evaluation of contributors to nuclear safety. The first accident in 1979 at the TMI-2 plant near Harrisburg in USA demonstrated the importance of the human factor to the whole nuclear community and the second accident in 1986 at the Chernobyl unit 4 near Pripyat, Ukraine demonstrated what the impact of a deficient safety culture could have on nuclear safety. The accidents themselves initiated many safety improvements at other NPPs around the world, but still the major share of safety improvements made have been based on lessons from the international exchange of operating experience.

These two accidents have had a major impact on public acceptance of nuclear power and some countries are today actively discussing a phasing-out of their NPPs. The whole nuclear community has learnt the lesson, that

> *The nuclear industry cannot afford events leading to distrust among media and the public.*

an accident anywhere is an accident everywhere. Utilities and regulatory bodies have understood the need for co-operation on safety issues.

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

> *It is in the interest of the nuclear industry to share good practices, because the public judges it according to its worst performers.*

ensuring nuclear safety. Design methods have been improved in various ways, including design certification and the review of safety concepts in the design. Other methods include the specification of a reference set of safety requirements to be applied in operations. In operations, guidance has been developed in procedures and documentation. Work has been based on an approved quality assurance system. Studies on human factors have been used to develop and maintain high compatibility between control room design, training and plant documentation. Safety authorities review documents and inspect work practices at the NPPs. All these activities combined have contributed to the high level of reliability reached by European plants. The development illustrates that managers have not only looked at the profit the plants are generating, but

have also committed themselves to maintaining safety at a high level. In a broader context this strategy is the only possible way for the industry to remain viable.

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. Unfortunately, as the Ontario Hydro case has

> *It is easy to lose crucial competency under economic pressures.*

shown, 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. If that is not done, organisational problems can be latent and result in the need to hold an extended outage before it is prudent to continue operation. The cost of such an extended outage can be very high and it represents major economic risk.

Organisation and management in the nuclear industry is similar to other process industries, but there are also important differences. A reactor contains a large amount of highly radioactive

> *Nuclear is similar to other industries, but there are also important differences.*

material and it cannot simply be shut off, but requires continuous attention. Safety is therefore a paramount driver in organisation and management. Nuclear power is also a highly political technology where mistakes can be extremely expensive. This self-evident fact needs to be borne in mind when organisational changes are made perhaps due to the utilisation of business consultants who might not be fully familiar with the requirements for nuclear safety.

An explicit discussion on organisational factors in nuclear safety is relatively new and it places the emphasis on the management and organisation of the work processes that are needed to ensure the continued safety of NPPs. Managers at nuclear power plants have to some extent applied methods and tools which have been used in other industries. These have made it possible to make operations more efficient, but there are some question marks regarding the applicability of common business management models and the need to adapt them. The main difficulty in managing a NPP is to maintain an overview of the organisation, its resources and people which are needed to achieve a viable commercial outcome and to ensure safe and efficient operations.

2.2 Drivers of change

The same drivers of change have operated in most European countries. Simplifying the picture one can divide these into political, societal, economic and technological drivers, which have interacted to produce the changed environment in which NPPs operate

today. 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 matter of unplanned outages.

In the current situation, economics and the political context, not technology, are the greatest obstacles to the construction of new NPPs. The economic risk of the capital investment is very large, because unexpected

Safety is not only connected to the risk of accidents, but also to the risk of unplanned outages due to safety concerns.

delays can occur in the licensing process, the public acceptance of nuclear power may change, and there are large uncertainties in the future price of electricity. The absence of new projects has led to reduced business for designers and vendors. A consequence of this has been that it is becoming more difficult to maintain competency in the design of NPPs. The decreased volume of projects has also led to the decline of research and development (R&D) activities and corresponding difficulties maintaining core competencies in areas such as neutronics and thermo-hydraulics.

A shrinking vendor business may reduce available competency in NPP design and operation.

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 moving into the regulatory regime. International co-operation has brought harmonisation into national regulation and safety practices, but there is still a large variation in regulatory structure and approaches across the European Union.

New tools such as Probabilistic Safety Analysis (PSA) have been brought into the regulatory processes. Better technologies for analysing events have decreased the uncertainties in the predictions. The regulation of today places requirements on beyond design base accident mitigation. The result of these changes is that the burden of proof that the NPPs are operated in a safe manner has been increased. New aspects of regulation have also been introduced with legislation on free competition and environmental protection.

The burden of proof that the industry is running NPPs in a safe manner has been increasing.

The nuclear utilities have responded to the changes in their environment 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. There are many similarities between organisations in general and organisations managing NPPs, but there are also important differences. The most important difference is the very high safety requirement, which is due to the fact that the reactor requires continuous attention and that failures in this regard can lead to hazards. A NPP is also a very complex system, which, for safe and reliable operation, demands 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, can sometimes make it very difficult to predict in detail how a NPP will behave in a specific situation.

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 of NPPs will need

Ageing plants and people can cause various problems if not approached early and in a systematic way.

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. When these pressures are combined with a need for cost reductions there is an increasing danger that competency will be reduced at a time when not only does it need to be maintained, but it actually needs to be enhanced.

Arguably, the largest problem confronting the nuclear community, at present, is the disappearing societal support for nuclear power. During its early phases nuclear technology was seen as very advanced, but as the media have tended to project an image of backwardness and danger, this has made it even more difficult for nuclear utilities to recruit the young, highly skilled, persons they will need for the future. This presents a strategic long-term issue, which needs to be solved by the industry concerning organisation and management.

The earlier societal support has in some countries turned into a situation where even civil disobedience is tolerated as a way of expressing opposition to nuclear power. These political changes bring with them a

A lack of good safety management at any nuclear installation is perceived by the public as a lack in all installations.

danger of a polarisation whereby the nuclear industry may be forced to close itself to media and public scrutiny. Such a development is likely to be counterproductive in a

society demanding greater transparency in decision-making processes. It appears necessary to build future communication processes on openness and interaction both in the local communities and on a more global political level. This development can be supported by additional participation and involvement of personnel at all levels of NPPs.

The development of information technology and computer networks present new opportunities for increased safety and efficiency in the operation of NPPs. Process design using computer based support makes it easier to avoid

> *Information technology can provide new opportunities for better communication and access to knowledge.*

design errors. Plant wide information systems make it easy to integrate relevant aspects of operation. Maintenance information systems facilitate trending for an optimised approach. Computer networks can make the information available anywhere. A rapid exchange of operational experience on an international level is also facilitated with the new systems. The use of information has actually made possible a new kind of plurality whereby people in their work rely on many new contact fora.

2.3 Responses to a changed environment and dangers in that process

The nuclear industry has adapted to the changed environment both in proactive development processes and in more unconscious reactions to new needs. In this process of change organisational factors become more important. When large changes occur it may also 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.

2.3.1 Deregulation

The deregulation of the electricity market has brought about extensive restructuring in ownership through privatisation, mergers and acquisitions. The organisational structure has, at the same time, been made flatter with fewer organisational levels in a process of decentralised decision making. These changes have been motivated by a quest for greater efficiency, but they have also in some cases introduced unexpected problems.

The restructuring of ownership may introduce problems in maintaining competency especially if shareholders perceive that there are overlaps in organisational functions.

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

> *A restructuring of company ownership can sometimes cause problems in organisation and management.*

> *Removing hierarchies in the organisations can sometimes create unexpected problems in channels of communication and allocation of responsibility.*

levels of management is sometime more difficult in a "flattened" organisation than in the old hierarchical and bureaucratic organisation.

One consequence of change is that the role of managers at NPPs has changed. They face new challenges, which require them to master new skills. In the past the role of the managers was more focused on technical aspects of NPP design and operation. Now the most important role of the management is in many cases to manage the process of change. This includes the creation of a vision for the organisation and communicating and implementing it. This has to be done without disturbing any of the crucial plant activities in the reallocation of resources. During this process, it is easy to lose the margins necessary to cope with unexpected events and consequently run into a danger of unplanned and extended outages. There is a need to adopt a new style of management, which is motivating, but at the same time sensitive to possible overloading of the organisation and its members. Managers in the NPPs of today have a very important role in ensuring continued safety, but the sometimes conflicting demands, which are placed on them, can make their position difficult.

2.3.2 Decentralisation

A decentralisation of decision-making is mostly advantageous, but carries with it a need for improved co-ordination. Decentralisation also builds on willingness to co-operate, which may be difficult to achieve if people play power games. Decisions should be made in a timely manner, because indecision can also be dangerous. When decisions are made under uncertainty there will always be cases when the initial decision taken has to be improved. In such cases the managers have to have the courage to retreat from a path which turns out to be erroneous. These issues should become a part of the daily work for high level managers where visions are balanced with urgent actions without losing the overview of the situation. In an overloaded organisation there is an increasing danger that this loss of overview will occur.

Even if plant activities are well supported by procedures and standardisation of work, the effects of organisational change may cause

> *In a pursuit of efficiency it often easy to overload key people.*

difficulties unless emerging deficiencies are detected immediately. 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. Such problems may be detected only in systematic assessments in which the whole organisation participates.

In some European NPPs there has been a shift in the way technical resources are managed and procured. Previously, technical departments were the drivers of plant changes, but now they are viewed as suppliers of services to operations very much in the same way as outside vendors. When this management style is utilised, the relative power of technical units is reduced. This can result in stopping of the continuous process of design improvement. Over a plant's lifetime this can result in difficulties in maintaining the plant in an acceptable state for continued operation.

2.3.3 Outsourcing

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,

> *When activities are outsourced, there is a danger of losing overview and competence. Outsourcing makes it increasingly important to identify and manage core competencies.*

with the result that some of the issues of corporate continuity and breadth of knowledge that one might normally expect of safety or operational personnel are much less in evidence than might otherwise have been the case. The resulting narrow specialisation, lack of corporate commitment and apparent short-termism not only has implications for the design and succession planning of any given organisation, but may have potential implications for the successful management of safety.

However, not only is it possible to argue that the technical resource might be over-specialised, but it is also possible to argue that there may be significant benefits associated with such an approach. The principal counter-argument is, of course, that the manpower specification can be so exacting that the very best resource is recruited for the job, and that this matching is an ideal way to secure customised resources.

Notwithstanding these observations, and the possible implications for safety and human resource management, the concern nevertheless remains that, because of a lack of strong corporate ties, there may be a possible dilution of responsibilities. If there is a widening vertical information gap in the organisation, outsourcing may not be a wholly appropriate way to undertake certain types of manpower resource management.

2.3.4 Increased competition

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

> *The nuclear industry has been very willing to share good safety practices, but increasing competition may change this situation if it is not forcefully prevented.*

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 search for cost saving it is often too easy to identify apparently non-productive functions in the organisation without a proper recognition of their contributions to long term safety and efficiency. A reshuffling of resources between organisational units can leave some of them on a level where it is not possible to maintain their core competency. Maintaining organisational memory and sound succession planning may also become troublesome particularly at the present time because the recruitment of young people is increasingly difficult. The search for savings also creates pressure for reductions in research and development resulting in a reduction in overall com-petency in the long term.

> *Organisational restructuring and change carries increased risks of losing competency.*

For effective management of human resources at an NPP there are various aspects to be observed. The competency of the personnel has to be maintained over the life-time of the plant and this may involve considerations of what has to be produced in the organisation and what can be procured from outside. A second important issue is the need to maintain public confidence both at a local and a national level and this can only be achieved the public have an image that plant personnel have complete knowledge of all relevant safety requirements. A third important issue is to maintain interest and involvement in international co-operation so as to be responsive to innovations and to promote harmonisation in safety management practices.

2.4 Challenges in 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

> *Safety and efficiency is not the result of some single program, but is the combined result of all activities at a NPP.*

efficiency are not the result of a single factor or program, but instead depends on all activities. This recognition implies that a balanced approach is utilised where resources are allocated according to their influence on the goals set by the organisation. The identification and implementation of improvements in safety and efficiency depends on both management practices and individuals. In a search for new ways to approach safety and efficiency a communication process becomes important for proper weighting of goals and action alternatives. Finding new concepts for modelling how people and organisations function may provide an important step forward in this endeavour.

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

> *Incident analysis, performance indicators and peer reviews are used to assess organisational performance.*

effectively, as possible. There is a clear recognition that organisational factors have to be taken into account, but these considerations have often been implicit and performed in an intuitive manner. The challenge, therefore, is to make the relationships between organisational factors more overt and a part of the daily work of managers on each level in NPPs. Some of the organisational tools that are applied are quality systems, incident analysis, safety committees and peer reviews. The real challenge, however, is to be able to see the shortcomings of these practices and to be able to predict the effects of their interaction.

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. The integration however introduces additional dependencies in the organisation and the interactions between technical and organisational performance, which have to be understood and handled. This will also necessitate internal discussions to give indications of emerging problems. This arrangement may, however, facilitate the identification of causes of human errors in order to promote an efficient analysis of organisational performance.

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. There are also various schemes for carrying out peer reviews, which place different emphases on selected organisational factors. Due to the absence of a common framework for facilitating an exchange of experience concerning organisational factors, the results obtained are seldom comparable and often seem to depend more on the team carrying out the review than the organisation that is being reviewed. There is an apparent need for a comparison of different methods, therefore, and iteration seems necessary between theory and practice so as to facilitate the development of a consensus on how organisational assessments can be carried out.

2.5 A regulatory perspective

When nuclear power was introduced regulation was very much in its infancy. Today, however, most regulatory practices are so well developed that some within the industry even argue that resources spent on regulation could be decreased without any major impact on safety. This view does not however correspond with the actual situation, because, not only is society demanding increased safety, but there are some new issues (e.g. "downsizing") that have been introduced into the regulatory arena that complicate the subject still further. Regulators are also, to some extent, influenced by the changing role of nuclear power and an ever-present requirement to become more efficient and effective.

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. Whilst there is discussion on the merits of introducing prescriptive regulation in the field of organisational factors at this time, there is a realisation that additional regulation in this area may be necessary in due course.

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. The problem, however, is to create a common understanding of crucial components of the safety activities in NPPs.

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. Therefore as well as responding to regulatory pressure, significant change, if required, will have to come from within the

Some regulators have moved from detailed prescriptive regulations towards a general oversight of important safety activities.

NPPs. If it is achieved, typically via self-discovery, this is also likely to be a highly effective and sustainable approach in the long run. However, it might still prove necessary to apply regulatory pressures in order to increase the awareness of managers so that they can anticipate, identify and rectify organisational deficiencies for themselves. For completeness, suitable regulatory approaches should, where appropriate, also take account of good safety practices and self-assessments carried out by the utility.

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

The creation of regulation on organisation and management requires a delicate balance between utility and regulatory roles.

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. Naturally, people can be sensitive to criticism and any possible criticism has to be expressed in an appropriate manner in order for it to be accepted and acted upon. Whilst recognising such sensitivities, these should not be allowed to get in the way of constructive criticism and comment which may well be the best way to achieve effective nuclear safety improvements.

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

The pressure of regulatory bodies on NPP operators to show that their safety culture is good had sometimes caused confusion.

culture is good can therefore cause confusion if the process is not progressed in a logical, incremental fashion. Notwithstanding the precise details and ramifications of the safety culture concept, it is, nevertheless, important that the regulatory body can act, and is seen to act, decisively if it detects early signs of organisational degradation. To decide when interventions are needed requires both insight and understanding. Regulatory processes should not be seen to be hindering or delaying justifiable safety improvements in organisation, but neither should NPP operators introduce organisational and management changes which they know could have the potential to degrade nuclear safety. The regulator, therefore, whilst retaining the right to intervene at

all times, must also insist upon clarity with respect to organisational and management arrangements and seek continuous improvement wherever appropriate. As well as operating as an enforcer, the regulator also has an important role as a coach, and it is important that the operators of NPPs recognise these two distinct facets of the regulator's mission when engaged in exchanges on the subject of organisational and management factors.

3. Needs and methods for organisational assessment and development

3.1 Describing 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

> *Safety has to rely on systems, but systems cannot function without individuals.*

task of management is to maintain this control system functional which means that feedback on its performance has to be used for initiating necessary control actions. To help the management in this task there is a benefit of using certain agreed ways to describe different parts of the organisation and their interactions. A common way of describing an organisation is to present an organisational chart, but such a description gives only an overview of the lines of responsibilities and reporting. Another part of the descriptions of how work is organised is embedded in the quality systems which are used at most NPPs. Instructions and procedures also contain descriptions of how the work is organised.

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. 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 which make it possible to understand how the organisations function in various tasks.

Goals and *requirements* govern all activities in organisations. They are partly imposed from outside and partly defined within the organisation. An organisation responds to goals and requirements in a process of planning and execution. In that process various tools and methods are used to achieve the required work quality. Finally, a collection and analysis of operational experience provide the feedback for further refinements in control processes.

Authority and *responsibility* are important in considering the tasks people do within an organisation. A common requirement in high reliability organisations is that there should be a clear line of authority and responsibility where everyone has a superior to whom s/he reports. The line organisation is typically represented in an organisational chart. The assumptions concerning authority and responsibility are written into organisational handbooks, but are also implicit in procedures and practices.

A few basic activities can be used to break up tasks into smaller parts. One set of such basic activities is to manage, construct, operate, maintain, verify and analyse[2]. These activities can operate on technical systems or on resources used by the organisation. In a discussion of resources the following different types of activity may be separated out; financial, human, information, tools, methods, space and time.

Work processes are sometimes considered complementary to the line organisation. The work processes provide a dynamic and horizontal view and the line organisation a vertical view of the organisation. Considering work processes at a NPP there are evidently many different ways to define and structure these work processes. 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 how they interact. For this purpose formal tools have been developed.

3.2 Safety management in practice

Nuclear power plant operators have at least implicitly understood the impact that organisation and management can have on performance. Many strategies and practices are therefore used in which organisational

> *Many good safety management practices are applied by the industry, but these may still not be enough.*

factors are relevant. One assumption of the ORFA project is that when the organisational factors and their relationships are made more explicit it should be easier to maintain an overview and thereby to achieve better control of safety and efficiency.

3.2.1 Organisational strategies in use

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 towards a matrix approach whereby tasks cut across several lines within the organisation. In some cases this type of organisational change has caused problems of co-ordination.

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

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[2] Carl Rollenhagen: A framework for assessment of organisational characteristics and their influences on safety, AMM–ORFA(99)–R02, May 1999.

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. 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.

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. 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 takes some time for the first quality systems 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, emphasising requirements associated with the work processes as well as the resulting products of their application.

Many European nuclear power plants have formed *safety committees* to support the highest 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 modification proposals, safety cases, etc. Safety committees have formal links with the regulator, whereby the latter receives meeting minutes and, sometimes, participates in meetings.

The nuclear industry as a whole has been exceptionally willing to share good organisational 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. Opportunities for managers to visit other plants to see different practices is also important in promoting a better understanding of the impacts of management on performance.

3.2.2 Assessing organisational performance

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 efficient in 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" environment. Investigations should 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 to some difficulties in making workable recommendations for organisational improvements.

Most European nuclear power plants use the WANO *performance indicators* to benchmark their performance 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.

Most nuclear power plants have been involved in *peer reviews*. IAEA, for example, offers peer reviews to member states within the OSART, ASSET and ASCOT programmes. WANO and INPO offer similar peer reviews to their members. A peer review is carried out in a similar way to a quality audit, but the scope of the assessment is broader. An OSART review will typically involve up to 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.

Performance appraisals are used at many nuclear power plants as a systematic tool to assess performance and set personal goals. The appraisals are a formal discussion between the jobholder and line manager, as part of an overall 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.

Many nuclear power plants have used questionnaires to assess their *organisational climate*. 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.

3.2.3 Organisational culture

The concept of safety culture was introduced to the nuclear community after the Chernobyl accident. Safety culture is also commonly proposed as an organisational factor to be assessed. Thanks to activities of the IAEA the concept has been clarified in several excellent publications, but many NPPs still feel it difficult to make the concept operational. The concept itself stresses an important point of which many researchers in management science have been aware, i.e. that the organisational culture of a community is an important underlying factor for understanding its behaviour.

There are many definitions of culture. In a discussion of organisational culture the concept is often divided into three levels, *artefacts*, *norms&values* and *underlying assumptions*. According to this division the artefacts are the visible in organisational structures and processes. The espoused or implicit norms and values are reflected in strategies, goals and philosophies. These two levels can be observed and measured by various methods, but the underlying assumptions, which are unconscious taken-for-granted beliefs, perceptions and feelings, are far more difficult to assess.

Organisational culture undoubtedly has an important position as system of shared assumptions and meanings, which permit people to interact in an efficient way. Organisational culture is not created, but it is a result of interactions between people over time. This means that it is difficult to influence the organisational culture and it will change only slowly. Strong characters sometimes have a large influence on organisational culture, but typically new people bring in a gradual change. Organisational culture is often maintained and carried forward by those who have had a long career in the organisation. Sometimes one finds organisational deficiencies, which can be attributed to an organisational culture that is not suited to the mission of the organisation.

In using 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.

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. An assessment of safety culture on the two upper levels can be done with some degree of reliability, but it is far more difficult to reach the level of underlying assumptions. This

level is also based on a national culture, which has been conveyed through societal norms, the educational system and the business environment in the country.

There has been research aimed at investigating and categorising national cultures and their impact on organisational culture. This research can help in understanding some mechanisms, which seem to set the framework for the observed diversity in practices of co-operation and management in different cultural contexts. There is also anecdotal evidence that the cultural diversity between countries in the European Union has an influence on the organisational solutions in operating the nuclear power plants.

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 wholly 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.

These issues are becoming increasingly important, because companies are splitting up and merging at an increasingly rapid rate. It is also important to understand the cultural background and its influence to achieve an efficient exchange of operational experience. The concept of culture is also important when the results of a peer review are assessed, because the assessors are also products of their own national culture, which may lead them to regard unfamiliar practices as being unacceptable.

3.3 A systems approach towards human errors and organisations

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. A central concept in

> *There is a large range of models, from simple aids of thought to refined instruments for prediction and control.*

a systems approach is the concept of a *model*. A model can simply be an aid to thought, but it can also be refined to include explanations of how important variables influence each other. Models are usually developed to serve a specific purpose.

A simple model of the origin of human errors may in this connection serve as an example. Assuming that they are not intentional they may be seen as caused by a

resource demand conflict caused by hidden deficiencies in the technical or organisational system. If multiple errors add up there may be a simultaneous break down of several protective barriers to leave the plant vulnerable to an accident.

According to a systems approach a system interacts with its environment and can be subdivided into parts. Considering organisational aspects of nuclear safety five different subsystems can be identified: the environment in which the NPPs are operating, the technology used in their construction, the individuals working at the plants, the groups and their norms of behaviour and finally the organisation with its structure and work processes. These five subsystems interact and there are organisational factors important for nuclear safety within each of the subsystems and at their interfaces (Figure 1). Applying an implicit interpretation of the concept of safety culture one could say that it should be a view, which permeates all interactions between the five subsystems.
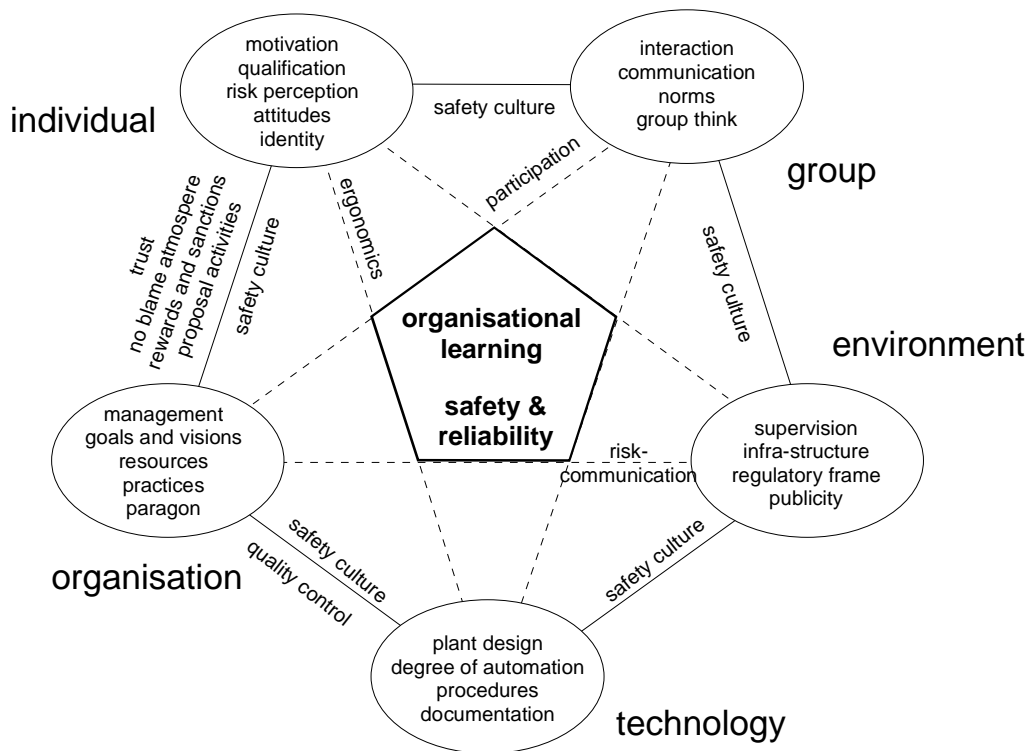
Figure 1. The five interacting systems of nuclear safety.

Considering organisational factors according to a systems point of view would imply the definition of a set of basic concepts to allow for a modelling of their interactions. Unfortunately there is no consensus on what these concepts would be. Within the environment of the NPPs important factors are the regulatory framework, societal attitudes to nuclear power and the market price of electricity. Important contributors in the technology sphere are plant design, the degree of automation and operating procedures. The function of the organisation is connected to visions, goals, resources

and practices. On a group level communication, norms and shared experience become important. On an individual level factors like motivation, qualifications, attitudes and identity are crucial components in determining behaviour

In spite of the need to apply systems approaches to managing change there are unfortunately very few methods and tools available to support the process. The reason is that organisational systems are complex, closely coupled and non-linear. Complexity makes it difficult to track all paths of influence and unexpected interactions can therefore cause surprises in system behaviour. A close and rich coupling between various parts in the system implies that there is no root cause for observed behaviour, but a situation where everything influences everything else. Non-linearity of the interactions can create situations where subtle changes may have a very large influence on overall system behaviour.

3.4 Needs for organisational assessment and development

In the management of organisations one can identify the following basic needs

− to understand, what the important characteristics are and how they interact,

− to predict, how certain actions are likely to influence organisational performance,

− to detect signals of deteriorating performance and to initiate necessary actions for improvement.

These basic needs can be expressed as a variety of more detailed needs. One question is connected to the analysis of incidents and to the characterisation and identification of organisational deficiencies. Another is the methodology of audits to make them efficient without creating negative impacts in the motivation of the organisational units audited. There are also many questions connected to building up reporting systems for the effective collection of operational experience. It would be beneficial if organisational factors could be reflected in PSAs to make it easier to target improvements not just to the technical subsystems. There are many questions to be answered regarding the selection of people for certain positions and supporting their training in the most efficient way. The transfer of good operating practices between organisations and countries can be enhanced with a better understanding of the cultural aspects of organisations.

There is also a generic need for additional interaction between theory and practice to make proposed methods applicable to day to day management practices. In order to

reach that goal there is a need for integration work in extracting a common understanding from the methods and tools suggested in the literature. Ideally such integration and validating work could be performed via a research project which would for example, monitor one of the projects for either organisational assessment or organisational change at one or several nuclear power plants in Europe. An additional benefit could be obtained if such a project could integrate experience and practices from several countries.

More systematically and exhaustively, 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 the 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.

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 more acutely aware of the parts of their organisation which function more autonomously.

The planning process has to rely on efficient methods and accurate information to build a viable plant strategy. That strategy should include a simultaneous management of technical, human and

> *The process of identifying problems, examining them and allocating resources for their solution is important in all organisations.*

organisational resources. It can also try to identify indicators of good performance and margins within which recovery is possible if some unexpected dysfunctioning occurs.

3.5 Methods for organisational assessments

3.5.1 Some general problems

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. There are, however, many difficulties, which have to be taken into account in this work. Already in Europe one difficulty in sharing information on organisational factors comes from differences in how words are translated and interpreted. Another difficulty is connected to the cultural environment and its

characteristics. To make methods for organisational assessments more easily shared they have to undergo a national validation, which describes underlying concepts and practices. Already the word, "organisation" is very broad and has many different meanings.

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 person 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. Assessors sometimes negotiate a kind of agreement with those to be assessed as to how data will be collected, validated and reported. This can provide a framework within which further problems can be discussed. Some of the difficulties can be solved by training the assessors, but training alone cannot compensate for the need of insight, tact and discretion.

Another difficulty is connected to the fact that all organisational factors interact with each other. It is therefore difficult to build models of organisational behaviour in the form of cause-consequence relationships. A theory of how performance is related to various organisational factors could help in this respect, but unfortunately no such theory exists at present.

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. Also, the use of different approaches can sometimes provide additional validation of the results that have been obtained.

3.5.2 Analysing events

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. If for instance recovery is delayed it is an indicator of organisational performance. Good performance often relies on margins and flexibility within an organisation to provide the resources necessary to cope with unforeseen events. A high reliability organisation has to have resources to cope with contingencies and

> *There have to be margins and flexibility within the organisation so that it can cope with contingencies and unexpected events.*

sufficient flexibility to select new patterns of behaviour. The way of doing that depends to a large extent on organisational culture, but should, when used, be given proper credit in the event analysis.

In the analysis of events it is common practice to select different routes depending on the safety importance of the event. This is important not to overburden the organisation with irrelevant information, but the practice also introduces a danger that important lessons from minor events are lost. It is important to record minor events as well, because a repetition of events can give a signal of deeper underlying problems. Many plants have for that purpose established systems and databases to provide a statistical analysis of events, which can support an evaluation of organisational performance

The event analysis methods should provide mechanisms and opportunities for allowing those involved to ask themselves what factors might increase the likelihood that similar events will occur in the future. When typical failure modes are seen in a family of events it easier for the analysts to identify weaknesses in the technical and organisational systems.

An event analysis will result in a list of recommendations. Recommendations, which influence technical systems, are often easier to implement than recommendations for changes in organisational structure. The recommendations are typically part of a longer list of development needs, which provides an input to the activity planning and further initiation of specific development projects.

3.5.3 Work processes

Some organisational assessment methods focus on work practices and modes of communication at the shop floor level. To a certain extent, aspects of some organisational factors can be observed at the shop floor level. These methods concentrate on examining how activities are organised and how people execute certain tasks such as start up, shut down, regular testing, maintenance, installation, etc. The methods build on safety rules and requirement criteria, and an assessment is made with an emphasis on tools and methods, on communication aspects and on how feedback is used to improve the organisation.

Other organisational assessment methods focus on how processes, which are important for safety, are organised. Such processes include, for instance, incident reporting, the evaluation of operational experience, the plant modification processes, etc. A common regulatory requirement is to carry out a periodic safety review within a five to ten year's time frame. Typically such a safety review today would also involve an assessment where organisational factors have to be examined.

The organisation plays an important role in the way technical problems are approached. Important considerations are how the problems are identified, how they are examined and how resources are allocated for their solution. There is a need for tools to assess each of these processes in detail. Other tools could provide a more global view of the organisation, but could then be supported by the more detailed views.

3.5.4 Indicators of organisational performance

Assessment methods can also be connected to a single organisational factor and an indicator, a questionnaire or a checklist can then be optimised for that assessment. For example, a leadership dimension can be assessed through indicators for management involvement, openness of communication, contentment with work, belief in future, etc.

NPPs in some countries have identified indicators, which aim at quantifying organisational safety performance in a more global sense. The tools selected are based on the use of questionnaires, which assess the state of certain organisational factors. Some of these tools have been standardised to support an inter-comparison between power plants, industrial sectors and countries. Such indicators have a value in providing some kind of normalisation for what can be considered excellent, good, average and below standard in observed performance and practices.

3.5.5 Organisational development

There is also a need for quantification, because actions for improvements will always need the allocation of resources. A balanced control can be achieved only if the marginal improvements of added resources can be assessed. Ideally a tool should be able to give an estimate of the improvement in safety and efficiency to make it possible to compare it with the costs of the change.

Managers assemble inputs of various kinds, which provide indications of problems and opportunities. Based on an assessment of their relevance in a consideration of the mission and goals of the organisation some of them are selected to be acted on. The actions often have some influence on the organisation and sometimes a complete reorganisation of some branch or office is initiated. Sometimes changes are implemented gradually to gain experience of new ways to organise before a full implementation is undertaken. Such a gradual implementation may also help in overcoming the resistance to change, which sometimes can be seen in organisations. A good principle is to involve the people affected by the change by giving them specific tasks of planning and implementation of the change. When these processes are properly

conducted, they can also improve the communication between different parts of the organisation.

All changes carry costs and anticipated benefits. Changes are typically made when the benefits are judged to outweigh the costs. Changes however, also involve uncertainties which may increase the costs of a proposed

> *A consideration of the benefits of proposed changes has to involve also uncertainties and hidden costs.*

change. Quite often such hidden costs are underestimated. It is clear that increasing safety may sometimes carry increasing costs, but it is also evident that decreasing safety will carry high costs connected to the risk of an extended outage. An assessment of the need for changes should therefore include a proper consideration of uncertainties and the cost and benefits for safety and efficiency.

The ORFA group is convinced that organisational development also carries an opportunity to invest in the training of plant personnel with a corresponding potential for innovations in the organisational field. Such training can also provide plant people with words and concepts, helping them to create and refine organisational norms.

3.6 Some general observations on organisations

Incident analysis, audits, organisational assessment and peer reviews commonly produce recurring observations. Some of the observations relate to good practices and others to various difficulties in achieving an optimised performance. The observations described below do not pretend to be exhaustive, but are observations that may provide insights to the reader.

Company goals are not always communicated clearly enough to be either understood or related to available resources. Making a goal explicit helps managers to achieve it and allows them the scope to react if the resources allocated to it are not large enough. Sometimes there are conflicting goals and managers should be careful in explaining how they can be balanced against each other. If dual messages are given they may create confusion and stress in the organisation.

One important motivational factor is how the ownership of tasks is conceived. Personal responsibility and authority are strong motivators for achieving commitment. If that commitment is found, co-operation and participation are easier to develop.

> *Personal responsibility and authority are strong motivators for achieving commitment.*

Organisational changes should be carried out carefully and sufficient time taken in implementing them. Too many rapid changes may also create resistance, as people may prefer to wait for the next change before taking action.

People tend to forget things, which are not rehearsed regularly, and this may cause human errors. A remedy is to give people proper procedures and continued training in less frequently executed tasks. People also have a natural tendency to fall into routines that may drift away from accepted safety practices. These routines may become integrated as norms for a group, and in such cases they can be difficult to modify. Audits and reviews can counteract tendencies to deviate from agreed safety practices. Sometimes strong group norms may emerge and management should then be sensitive to their interactions with safety and efficiency. Managers may not be aware of slow changes, which occur in practices if they are not explicitly trying to monitor them.

> *When routines become integrated as norms for a group, they become difficult to modify.*

People respond to situations in the way they perceive them and not according to their possible safety implications. There is a need to maintain an overview and manage details at the same time, but it is easy for people to lose their overview of the organisation in a pursuit of details. People also have a tendency to allocate their attention to things, which are prominent, and not necessarily those things that impact on safety.

> *People respond to situations in the way they perceive them and not according to their possible safety implications.*

Organisations often have difficulty in identifying beforehand those situations, which occur infrequently and may require additional effort, support or resources. In order to avoid inadequate actions being taken in such situations it is often necessary to go beyond just prescribing better procedures or training.

Keeping described and actual work practices in line with each other requires continual effort. Sometimes it is difficult to achieve a balance between tightly proceduralised activities and knowledgeable involvement by people. When procedures are difficult to use there is a danger that informal work practices emerge with a corresponding danger for decreased traceability and repeatability in actions.

> *Keeping described and actual work practices in line requires a continual effort.*

A common observation from organisational reviews is that an organisational development has to be carried out from the inside, but that it may need to be initiated by an outside trigger. Organisations often seem to be aware of their problems but sometimes this information does not reach decision-makers. In such cases an incident can help in making available the means to improve all the more obvious.

> *Organisations seem to be aware of their problems, but there are often obstacles for this information to reach the people who can do something about them.*

There is always competition within organisations and sound competition can enhance efficiency. If competition makes necessary co-operation difficult, or if it initiates a power struggle, higher management has to intervene.

Organisational change is often viewed somewhat simplistically as a change in the organisation chart, but changes can carry deep, yet sometimes subtle consequences. Ideally an organisation should aim at an efficient management of human resources, but it is difficult to take all the contributing factors into account.

3.7 Good organisational principles

Various organisational assessments, peer reviews and research studies have identified many good organisational principles for increased safety and efficiency. Sharing these principles over organisational and national borders is not an easy task, but it can be facilitated by a better understanding of interactions between various organisational factors.

There is a consensus that high reliability organisations 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. This consideration should also be given to different phases in which the organisation is interacting with its environment.

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.

Organisational handbooks describe the activities and the mission of people. Company values and goals are written into policy statements. In the oil industry these principles are carried one step forward in the way high level managers reinforce their leadership by expressing their own personal commitments for safety into writing. This principle

makes it possible for anyone to verify that commitments for safety are respected by senior managers in setting an example for safety involvement.

A wise precaution for many organisations is to provide a certain amount of slack to cope with unexpected demands. For example, in some plants, operating crews are increased at the end of outage in order to carry out start up tests and evaluate their safety implications. An organisation should also include redundancy in crucial activities so as not to delay important decisions.

A just culture in the analysis of incidents is important 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. This does not exclude sanctions in case of conscious violations of safety rules or in cases where errors are hidden. Experience shows that these kinds of human errors are rare in the nuclear industry.

An organisation has to protect itself and its members from over-confidence. To some extent this attitude has to rely on a moral

> *An organisation has to protect its members from over-confidence.*

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. The obligations on personnel include honesty, truthfulness and abstinence from drug taking during work. If misconduct is observed, the necessary investigations have to be conducted.

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 high level managers to obtain feedback on how their statements and messages are interpreted by people in the organisation. It may therefore even be wise for them to have some person confidentially warning them when messages have been interpreted incorrectly or are not in line with conditions within the organisation.

Participation of the personnel in safety activities is based mainly on their ability to detect safety relevant issues in their daily work and to be able to influence the right people. The discussion itself can sometimes be more important in promoting aspects of a learning organisation than the action itself.

International participation and active discussions in safety projects tend to enhance not only safety-related activities, but also the efficiency of internal work practices for engineers, managers and others

> *There is a benefit of exchanging practices within an international project, because sharing enhances learning.*

who have to overview their 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. Without adequate insight into the problems it is often too easy to express unfounded criticism.

4. The ORFA project

4.1 Goals and content

A Concerted Action within the Nuclear Fission Safety Program was 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 SwedPower, Sweden. All partners in the consortium have ongoing activities, which are relevant to the subject. 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 on 1 August 1998 and it was formally ended at the end of the year 1999.

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. It was also the intent to build a basis for further research co-operation and activities.

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.

The work was divided into three work packages:

WP1 Needs and methods. Power utilities and nuclear regulators views on why they considered it necessary to assess and review organisational factors were collected. The partners assessed and adapted their own methodologies to the identified needs. What was required and methods were then compared and a document was prepared on how to treat organisational factors both in the regulatory system and at the NPPs.

WP2 Final seminar. A final seminar was arranged for the project partners and an audience outside the project to present and discuss preliminary results and conclusions. Wide participation from power utilities, regulators, vendors and research organisations was invited. Feedback from the seminar was used in finalising the report.

WP3 Major Conclusions and Final Report. Major conclusions on how to approach organisational factors in nuclear power at power utilities, reactor vendors, regulators and research organisations were presented in a final report. The structure and content of

the final report was supposed to be discussed during the first meeting. The report contains a state-of-the-art review of safety management strategies, an account of good operational practices, major conclusions and recommendations for further R&D work.

The project addressed nuclear safety on a broad basis and the results can serve as a guide on how organisational factors might be approached as a component of nuclear safety in the future.

4.2 The report[3] on 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. Berlin University of Technology, Research Center Systems Safety (FSS) conducted the work. On a generic level one can identify three types of requirements:

− 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).

When a specific task is initiated methods are identified to meet the requirements. 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 awaiting possible 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.

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[3] Bernhard Wilpert, Rainer Miller, Björn Wahlström: Report on Needs and Methods, AMM–ORFA(99)–R03, May 1999.

NPP / Utility
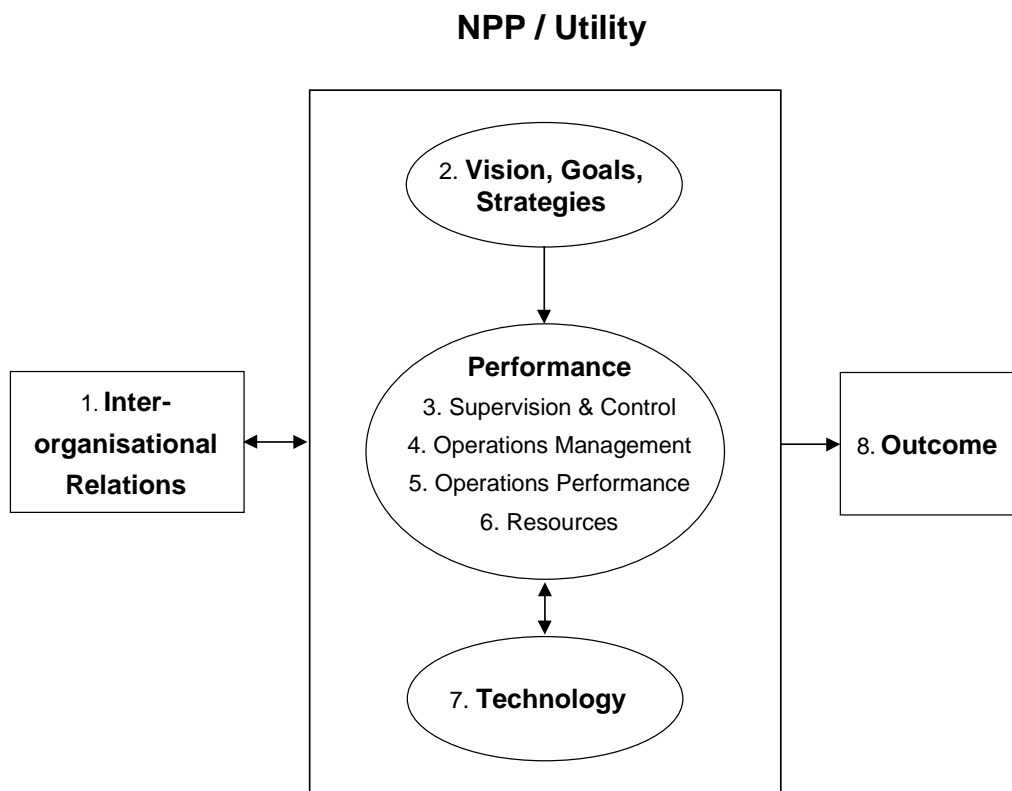
Figure 2. Organisational factors and nuclear safety: A categorisation of relevant variables.

In connection with the preparation of the report partners conducted a short survey among nuclear utilities and regulators on their assumptions on needs and methods for the assessment of organisational factors. The survey was based on an integrative model assembled from 15 relevant models of organisational factors. The integrative model was based on a categorisation of organisational factors where the "meta-plan" technique was used. This kind of technique is used to structure a complex domain into its constituent parts. Eight general categories were identified which formed the basis for the survey (cf. Figure 2). Nine questions on the treatment of organisational factors were formulated. The partners carried out the survey in slightly different ways depending on their contacts with nuclear utilities and regulatory bodies. The survey and a literature search served as the basis for a draft, which was discussed in March 1999. After a few rounds of redrafting and commenting the final version of the report was issued to the partners in June 1999.

4.3 The final seminar (WP2)

Ciemat in Spain, in collaboration with the Spanish utility organisation UNESA and the Spanish regulatory body CSN hosted the seminar. A total of 68 participants from 8

different countries and two international organisations attended 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 performances,

− to collect feedback on the draft report,

− to 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. The invited contributions were presented by the following persons C. Perea (NPP Trillo, Spain), A. Martin (CSN, Spain), J. Casier (NPP Gravelines, France), V. Madden (WANO, UK), D. Brosche (Bayernwerke, Germany), C. Boyd (British Energy, UK), J.-O. Hultquist (Ringhals NPP, Sweden) and J. Carroll (MIT Sloan School of Management, USA).

On the second day, group discussions were organised in five small groups, and a group reporter presented the results from the discussions in plenary session in order to draw together the 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?

In the final discussion the following issues were addressed:

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.

With regard to plant management challenges, it appears that managers cannot manage well if there are significant deficiencies in the institutional framework, that 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 wrong and a more adequate description could be missing.

The main messages coming from the seminar, which completed or reinforced the ORFA partners view, have been added in this final report. To document the exchange at the Madrid Seminar, a report[4] 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.

4.4 The main findings from the project

The exchange in the ORFA framework, the report on needs and methods and the final seminar highlight a few points. Firstly, there seems to be a lack of consensus regarding aspects of organisational factors and their

All agree that organisational factors make a difference, but there is no consensus on which factors are the most important.

relevance to the safe and reliable operation of NPP. Most practitioners agree that organisation and management are important factors to ensure safety, but many are of the opinion, that enough work already is done in that area. On the other hand, researchers claim, that 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

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[4] Björn Wahlström, Jari Kettunen, Pekka Pyy (eds.): Proceedings from the ORFA seminar in Madrid 21–22 October 1999, AMM–ORFA(99)–R05, December 1999.

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.

Secondly, 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, as well as renewed efforts 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.

Methods and tools are needed for assessing organisational performance and for selecting routes of improvement.

Thirdly, management of an NPP involves the task of finding an operational balance with a large number of sometimes conflicting requirements (Figure 3). The challenge for the managers is to find a suitable balance and to communicate that to the organisation in an understandable and acceptable manner.

traditions – renewal
formal – informal
self-confidence – willingness to listen
co-operation – competition
centralised – distributed
discipline – flexibility
focus on details – maintaining an overview
monitoring and reporting – confidence and accountability
short term versus long term optimisation
specific/practical – generic/theoretical

Figure 3. Important balances in NPP operation.

4.5 Towards the future

In Europe there is no short-term replacement for the electricity generated by nuclear power plants. Presently there are no realistic prospects for exchanging the present nuclear capacity to make energy savings or for use of renewable energy sources. At the same time there seems to be few realistic prospects for building new plants before the currently operational plants have served their duty. A major challenge for the NPP operators will therefore be to maintain the knowledge and skills needed to operate plants safely and efficiently.

In Europe it is expected that only modernisation and plant life time extensions will supply designers, licensees and vendors with projects enabling them to maintain their

competencies, but there is a risk that important knowledge will be lost. In this situation nuclear operators may be forced to pool their resources to maintain critical but expensive competency.

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 it they are linked to misconduct. The industry as a whole 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.

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. If the public attitude towards nuclear power becomes very hostile a dilemma may emerge, whereby the industry might attempt to protect itself against unfounded accusations by becoming more closed and a situation could then be created where it is even more difficult to achieve efficient feedback of operational experience.

One specific question, which has sometimes been discussed within the nuclear industry, is to what extent it would be better to have managers with a technical background compared with managers with managerial training. This question cannot be solved generically, but has always to be tackled on a case by case basis and it is clear that technical and managerial skills have to be combined. 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 in the future to find managers for various positions in the utilities and at the regulatory bodies. Interesting questions to be resolved in this connection are the qualifications top management should have and what kind of training they should go through.

The challenge for the industry to maintain competence can be met in three ways. Firstly, it is important to maintain a good image of the industry as a whole to be attractive for young people. Secondly, programmes to manage human resources on a long-term basis have to be put in place to make it possible to meet career expectations of people. Thirdly, an effective educational system has to be in place to supply the industry with skilled people. To meet the third challenge it may be necessary to reorganise R&D.

5. Conclusions and recommendations

5.1 Management of change

Changes within the nuclear 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 be some of 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. If organisational and cultural aspects of such a development are not understood well enough, there is a possibility that this could lead to undesired consequences.

The nuclear industry has to take a long-term view to maintain a long-term political accountability. That means that it cannot be managed in a similar trial and error fashion as some other industries may. 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. Continued success of the NPPs will imply that within given resource frameworks can cope with the political constraints and the risks involved. If the anticipated restructuring occurs NPP managers may have to reorient themselves to working together with their organisation in a global network which is providing resources for the continued improvement of safety and efficiency. Management to an even greater extent will then have to rely on insight and understanding in their strategic thinking to maintain crucial competency.

There is a clear consensus among managers both at utilities and within regulatory bodies that organisational factors are important components in *An open discussion of all possible associated safety problems is the only viable strategy for the future.* 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 such as change are being dealt with in a responsible and prudent manner.

5.2 Needs for considering organisational factors

Opening up a discussion on the forces of change and identifying appropriate responses will most certainly imply new R&D efforts. 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. There is a benefit if the tools and the methods on which the tools are based can be shared within the international nuclear community to achieve both the benefits of a pooling of resources and a better understanding of them over organisational and national borders.

There is little doubt that many of the issues, which have been highlighted in this report, have been considered and acted upon by managers in NPPs. However this has mostly been done in an implicit way, without too much systematic assessment and validation. There are also additional insights to be obtained by an increased benchmarking of good practices. Unfortunately it has been difficult to share good practices, because the extent to which they depend on organisational and national cultures have not yet been made explicit. NPP managers cannot get very much support from the existing management literature, because it is geared to the conventional industry where the safety requirements are not as stringent as in the nuclear industry. The organisational processes should also be described in greater detail to arrive at practical methods for assessing the multitude of organisational factors.

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. For that purpose, a constructive interaction

> *A constructive interaction between theory and practice can provide new methods and tools for organisational assessment and development.*

between practice and theory is necessary. The proper path to take in the development of methods for organisational assessments seems to be to concentrate first on various methods for self-assessment.

The NPPs in Europe have been built in different cultural and company environments and a proper documentation of them seems to be an appropriate strategy. In the first round an R&D project could make a survey of local practices in a more systematic and explicit way.

> *A three party co-operation (utilities, regulators, research) is needed to achieve a proper handling of organisational factors.*

Common and efficient components of such 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.

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 final 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 final 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, built on mutual respect, open minds and willingness on the part of the participants to discuss issues openly.

5.3 Needs for research and development

The 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.

The research above is related to the generic problems of managing change in an organisation. In approaching the European nuclear industry with proposed research projects, it is also necessary to recognise that

> *Research should concentrate on field studies and should in a short-term perspective address the most urgent questions.*

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.

To facilitate the efforts the following pragmatic objectives should be considered:

– efforts are concentrated on real cases of organisational change in nuclear plants or companies,

– data should be collected in the same format to support a systematic inter-comparison of important issues,

– each case study should be summarised with an account of lessons learned in the use of methods and tools,

– generic findings should be drawn and documented in a form to make them accessible across national and company cultures.

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

– development of theoretical models for the interaction between organisational factors and crucial components of performance,

– development of pro-active 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.

In conducting the research the following guiding principles were identified as being important:

– interdisciplinarity; an integration of technical expertise with psychology, sociology, management science and anthropology,

−   openness and trust; an understanding among the partners involved in the work that all will provide their own crucial inputs which will be discussed and assessed openly,

−   perceived importance of the work; correct priorities are given to different parts of the work and it will give the different parties possibilities both to learn and to give each other relevant advice.

> *Research projects in organis-ational factors should be inter-disciplinary and they should build on openness and trust.*

The nuclear industry is faced with many challenges, which have to be met for continued success. 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, which contribute to continued safety and efficiency. The ORFA partners have a well-established framework for considering issues connected to organisation and management. In the longer term they may be seen as the first nodes in a network working for a better understanding of how organisational factors contribute to nuclear safety.

> *The ORFA partners have a well-established frame of con-sidering issues connected to organisation and management.*

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Author(s)
Baumont, Geneviève, Wahlström, Björn, Solá, Rosario, Williams, Jeremy, Frischknecht, Albert, Wilpert, Bernhard & Rollenhagen, Carl

Title
Organisational factors
Their definition and influence on nuclear safety. Final report

Abstract

The importance of organisational factors in the operational safety and efficiency of nuclear power plants (NPP) has been recognised by many organisations around the world. Despite this recognition, however, there are as yet very few methods by which organisational factors can be systematically assessed and improved. The majority of research efforts applied so far have tended to be modest and scattered. The ORFA[*] project was created as a remedy to these problems.

The objective of the project is to create a better understanding of how organisation and management factors influence nuclear safety. A key scientific objective of the project is to identify components of a theoretical framework, which would help in understanding the relationships between organisational factors and nuclear safety.

Three work packages were planned. First, a review of literature listed out the identified factors and methods for assessing them. Then, a draft version of the present report was prepared to clarify the environment context and the main issues of the topics. 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 and will be used to give further guidance to the European Commission in the development of forthcoming research programmes in the field. The project has addressed nuclear safety taking a broad perspective, which reflected and took into account the views of senior NPP management and regulators.

The questions discussed during the project have been:

− how can organisational factors be included in safety assessments,
− how can good and bad operational practices be identified,
− 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 data on 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 for further research work in organisational factors?

[*] ORFA "Organisational Factors; their definition and influence on nuclear safety" is a Concerted Action within the Nuclear Fission Safety Programme which is running under the Contract N° ERB FI4S-CT98_0051 of the European Union between the seven partners VTT Automation, Finland, CIEMAT, Spain, Nuclear Safety Directorate, United Kingdom, HSK, Switzerland, IPSN France, Berlin University of Technology, Germany and SwedPower Ltd, Sweden.