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Management of change in the nuclear industry – Evidence from maintenance reorganizations

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Abstract

The nuclear industry and especially the maintenance activities have been under various restructuring initiatives in addition to continuous incremental change due to e.g. new technologies, ageing plants, deregulation and the change of generation. These changes have been experienced as causing stress and uncertainty among the workers. Also, changes have led to e.g. lowered sense of control, goal unclarity and lowered sense of personal responsibility over one's work. Organizational changes clearly are issues that have potential effects on safety. Both positive and negative cases on safety effects of organizational changes exist, and various accidents have been pinpointed to organizational changes in the company. In this report the challenges of management of change at nuclear power plants are considered mainly from organizational culture - perspective. The cultural perspective taken in this paper strives to combine technical approaches to human resources approaches. The report focuses on evidence gathered from studies made at Nordic NPP maintenance units, but the results and models depicted in the report are of general relevance in the nuclear industry. The report is based on four case studies of reorganizing in NPP maintenance units and on a literature review of change management at various other safety critical organizations. The report presents a framework for considering organizational changes and their safety consequences.

Key words

nuclear power, organizational change, safety culture, maintenance, human factors, change management

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NKS/MainCulture 2004 – 2005 Final Report

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1. Introduction

Financial pressures, change of generation and other changes in the environment have prompted many organizations in the nuclear industry to reorganize their practices (e.g. downsize, outsource, and develop team-based or matrix organizations). Change management has emerged as an important topic in safety-critical organizations. Plenty of research has been made in the area and numerous models of an ideal change process have been developed. Still a lot of the change projects fail or at least they are experienced as stunningly burdensome. Further, no uniform way to analyse the short and long term safety consequences of various changes exist. It seems that even though the challenge of managing organizational change is clearly interdisciplinary (combining e.g. psychology, management, engineering, sociology) the organizational solutions and the change initiatives tend to be considered only from one perspective (e.g. technical or personnel management). In the nuclear industry the same principles that are used for technological change are often utilised also in organizational changes. This means for example treating change as a rational and sequential process that can be planned in advance and implemented as it was planned. The reality of failed change initiatives has shown this picture of the world to be inadequate in modern safety critical organizations.

In this report the challenges of management of change at nuclear power plants (NPPs) are considered mainly from *organizational culture* -perspective. The cultural perspective taken in this paper strives to combine technical approaches to human resources approaches. By taking this approach we raise questions that are not usually explicitly taken into account in NPP change management:

- what are the organizational dynamics that affect the organizational change
- how do the structural changes affect the organizational culture and the individual employees in the organization
- what safety consequences can changes in the employees perceptions of their work have
- what safety consequences can changes in the cultural conceptions have
- how to better take into account all the aspects of an organization (structural issues, human issues and cultural issues) in change initiatives

The report focuses on evidence gathered from studies made at NPP maintenance units, but the results and models depicted in the report are of general relevance in the nuclear industry. The report is based on four case studies and a literature review of change management at safety critical organizations (see Appendix A).

1.1 Maintenance of a NPP as a context for the case studies

Maintenance activities have recently been under various organizational changes and restructuring initiatives, aiming at e.g. reduced costs, increased availability of the machines, better knowledge sharing and increased flexibility (Reiman et al. 2005b, Kecklund 2004). This development has been going on for years. According to Moubray (1992), maintenance issues have received increasing attention, which stems from a “rapidly growing awareness of the extent to which equipment failure affects safety and the environment, a growing awareness of the connection between maintenance and product quality and increasing pressure to achieve high plant availability and to contain costs.” (Moubray 1992, p. 1). Ageing plants and equipment (OECD/NEA 2000), the ongoing generation turnover (OECD/NEA 2001), and the deregulation of the electricity market (Bier et al. 2001) have been the main drivers in the recent organizational changes in nuclear industry (see also IAEA 2001; OECD/NEA 2002).

Maintenance activity at the NPPs is complex, distributed, and difficult to coordinate and control both safely and efficiently. Yet it has been surprisingly little studied and developed within the human factors paradigm. The work activities cannot all be proceduralized and the effectiveness of the work is based on the proficiency of the personnel and the culture of maintenance at the particular plant. Further, big multi-disciplinary organizations such as NPPs consist of numerous subcultures based on e.g. different occupations, tasks or physical location. Due to these features, it is often hard for a single worker to see the big picture and how one’s own work contributes to the overall safety and reliability of the plant. Further, the safest and the most efficient way of maintaining the plant and organizing the maintenance activities is not self-evident. Thus maintenance has been organized and reorganized in various ways across the nuclear industry (Bourrier 1999; Reiman et al. 2005a, 2005b). Maintenance has been a target for e.g. cost reductions, outsourcing, process re-engineering, and reorganizations. New ways of working, for example new maintenance programs and strategies have been introduced in the nuclear and other fields (see e.g. McKone & Weiss 1998; Moubray 1992). Also, matrix organizations, multidisciplinary teams and job rotation have been tried (Sterman et al. 1992; Kovan 2000; Bier et al. 2001; Kettunen et al. 2004). Due to these features the problems of organizational change manifest well in maintenance. There is thus a lot to learn from change management in maintenance to other areas of NPP operation as well.

1.2. Organizational changes and safety in the nuclear industry

According to our literature review of studies and articles on safety critical organizations (see Appendix A), organizational changes clearly are issues that have potential effects on safety. Both positive and negative cases on safety effects of organizational changes exist, and various accidents have been pinpointed to organizational changes in the company (e.g. the Bhopal chemical plant, see also HSE 1996a; Baram 1998). In the nuclear industry a fuel cleaning incident at Paks is one example of the negative outcomes of organizational changes.

On April 2003, a fuel cleaning incident occurred during a scheduled maintenance shutdown of one of the four units at Paks NPP in Hungary. The fuel assemblies damaged and radiation was let into the environment. The cleaning of fuel assemblies had been contracted out in 2000, but the scope of the work in 2003 was more extensive. As a summary of the review by IAEA (2003b) it was noted that the responsibility for operation of the fuel cleaning system had been turned over to the contractor, and as a consequence the fuel cleaning procedures were not developed, reviewed or approved by reactor operations personnel. IAEA (2003b) also noted communication problems between the organizational units, timetable pressures, and uncertainty over the safety significance of the work being done. The contractor worked without proper supervision of the Paks NPP. For a full description of the incident, see Appendix A.

Bier et al. (2001, p. 7–35) conclude their review the effects of privatization and restructuring of the United Kingdom electricity supply industry to nuclear safety: "The British experience suggest that the impacts of restructuring and downsizing cannot always be accurately predicted by licensees, and that reorganizations can impose burdens on the licensees in excess of their anticipations." They provide evidence of blurred the responsibilities and accountability for safety, of weakened morale, and of significant shortcomings in both the licensee's and contractors' understanding of the nuclear regulatory system and licensing requirements. See Appendix A for more details of their review.

Major organizational changes, especially one's requiring reductions in the number of plant personnel or other cost reductions (e.g. shortening the time spent for refuelling outages) have received increasing attention in the nuclear industry (IAEA 2001, 2003; Bier et al. 2001). Some common issues of concerns in organizational changes are the vague responsibilities about safety matters, loss of competence, deteriorating morale and employee motivation and stress and workload. Less attention has been devoted to smaller, more incremental changes in organizational structures, tools and practices. These are also organizational changes and being usually non-specific in duration, less immediate in outcomes and less analyzed in possible

consequences and interrelations, they are a potential source of gradual drift in practices and culture toward an unsafe condition.

The safety effects of reorganizations are difficult to evaluate. For example, leaving the organization as it is could in some cases be more risky than changing it. The evidence from accidents caused by organizational changes cannot be taken as a proof about the inherent risks of change. The accidents that have been avoided by changing the organization are not so evident as are the one's that have taken place. Thus the overall effect of change on safety is ambiguous. Further, the mechanisms of how safety can be affected for better or worse by organizational changes have remained unclarified. However, we state that *there is evidence that organizational changes in nuclear power plants are a potential safety risk*. There also are situations and cases where changes have to be made. These changes should be carefully planned, implemented and followed upon. A proactive safety management means that the needs for change are identified in advance before they lead to incidents or degradation in the safety of the plant and the changes are implemented with taking safety into account adequately.

1.3 The background and aim of this report

Within the NKS-R program in 2002-2003, case studies were conducted at the maintenance units of the Olkiluoto and Forsmark NPPs (see Reiman et al. 2004b, 2005a). Also within the Finnish FINNUS nuclear safety program a case study at the Loviisa maintenance unit was conducted (Oedewald & Reiman 2003a). The aim of these case studies was to assess the organizational culture of the maintenance units and to clarify the demands of the maintenance work.

One of the main findings of the case studies was a strong ambivalence toward organizational changes and changes in the working environment: On the one hand personnel realised the changes that have already taken place in the working environment and perceived the need to change organizational practices and optimise resources in order to cope with e.g. market pressures. On the other hand, they considered the idea of a change in one's own work as very stressful and inherently dangerous. One's own work was often perceived as being highly significant and as being incapable of change without increasing risks or endangering both nuclear and occupational safety.

This report continues the work by focusing on the changes that are taking place or have recently taken place in maintenance, and on the impact of these changes on the organizational culture and the safety and effectiveness of maintenance activities. The existing material (such as 32 interviews, CULTURE-survey at FKA, TVO and Loviisa NPPs) was reanalysed for this purpose and additional data was collected when needed. The main goal of the activity was to identify

good practices of change management and critical issues that have to be taken into account in all change initiatives at NPPs. The aim was to study how to anticipate the consequences of organizational changes to the safety and effectiveness of the organization and to identify what change strategies and associated structures would best facilitate the psychological characteristics of work that enable effective working. The report focuses on planned change initiatives that focus on the structures of the organizations, not on unplanned or gradual changes in the organization. The effect of these gradual and unplanned changes is only briefly tackled in Sections 5.3 and 5.4 when discussing organizational culture, and organizational drift and its effects on safety.

2. Different approaches to analyse and manage change

Choosing an approach and a method to analyse and manage the organization in a change situation is an important but a demanding task. Change management is an active research area within the organizational and management sciences and it means business for numerous consultant companies. Thus, there are a considerable number of theoretical and methodological approaches to organizational change (for reviews see e.g. Weick & Quinn 1999; HSE 1996a; Illes & Sutherland 2001). Further, organizational changes with different pace or intensity (e.g. incremental transitions vs. radical changes) may require different focus of attention and different methods. Additionally, different types of organizational changes (implementation of new technology, reorganizing of one unit, merger, downsizing, etc.) influence the personnel of the organizations differently.

Dunphy (1996) has suggested that the following elements should be found in any comprehensive theory of change:

- a) a basic metaphor of the nature of organization (e.g. organization as a machine with replaceable parts vs. organisation as an organism that develops and adapts intentionally)
- b) an analytical framework to understand the organizational change (e.g. change is an occasional interruption and driven by external pressures vs. change is a constant feature of organization driven by alert reactions to daily contingencies)
- c) an ideal model of an effectively functioning organization that specifies both a direction for change and values to be used in assessing the success of the change intervention (e.g. survival, growth, integrity, costs of operation, absence of incidents or occupational injuries);
- d) an intervention theory that specifies when, where, and how to move the organization closer to the ideal (e.g. change as a re-engineering of functions vs. change as participative organizational learning process)
- e) a definition of the role of change agent (e.g. prime mover who creates change vs. sense maker who redirects the constant change of the organization)

In practise, in most organizational change models that are found in the literature, change is described as a process consisting of set of phases following each other (Figure 1). Clegg and Walsh (2004) call these “waterfall” models due to their sequential and non-recursive nature. The elements of a comprehensive change theory that Dunphy suggests are usually more or less implicitly considered in these models. Nevertheless, even though they are implicit, the underlying ideas concerning the nature of organization or the ideal model of an effective

organization influence the way of implementing the change in practice. If the underlying model of the nature of organization is not discussed when planning change it is difficult to compare and choose appropriate tools to manage change. Then, again, it may be difficult to justify the chosen approach in the organization.

It seems that the nature of an organization is seldom debated in the nuclear industry. Nevertheless, we state that within the nuclear industry there exist commonly shared ideas of a well-functioning organization. Attributes such as careful, competent, systematic, open and responsible are often used when the nuclear organizations are analysed. The ideal seems to be that organizations work in a functional and controlled manner; they do their work as designed and achieve the goals that are set. The demand for anticipation and containment is prominent. This sets requirements for the change management too. How to assure the reliability of the activities in the organization that is in the middle of a change process? How to model the long term consequences of the change? This is a challenge since the general experience is that one has to prepare for a temporary downswing in the effectiveness of the work after an organizational change. The general wish is that the impacts of changes could be anticipated, especially the impacts on safety and public image, in addition to the economic impacts. The topics connected to the special requirements of change in these high reliability organizations are seldom tackled in the general management literature.

Nuclear industry has a long tradition in the area of safety management, which is, in essence, about anticipating the forthcoming risks and managing the unexpected. Thus, it is natural that change management in the nuclear industry is closely connected to safety management. In fact, change management can be seen as a part of the safety management. Integrating ideas from safety management and change management theories to plan, manage and analyse reorganizing initiatives at the nuclear industry is the one of the motives for this report.

2.1 Process for managing change

This report presents and utilises two different but complementary approaches to analyse and manage organizational changes in the nuclear utilities. First, organizational changes are analysed by the means of *process for managing change*. Second, the changes are analysed from the perspective of organizational culture.

In the *process model* the idea is to describe the change process from the planning to the post-implementation phase and discuss the key elements of management actions needed. This idea has been introduced e.g. by NEA (2004) and IAEA (2001). Different organizational changes are

viewed as sequential processes or projects that require certain change management steps to be taken in each phase of the change process. Both the IAEA and NEA state that the nuclear industry has a mature process for managing technical changes. NEA (2004) draws an explicit analogy between organizational changes and technical plant modifications. They state that the change management process should follow similar paths regardless of the object of the change (organization or equipment).

NEA (2004) has conceptualised the key elements of *a rigorous change management process* (Figure 1). NEA suggests that also the regulators may wish to see these elements addressed by the licensee when dealing with organizational changes.

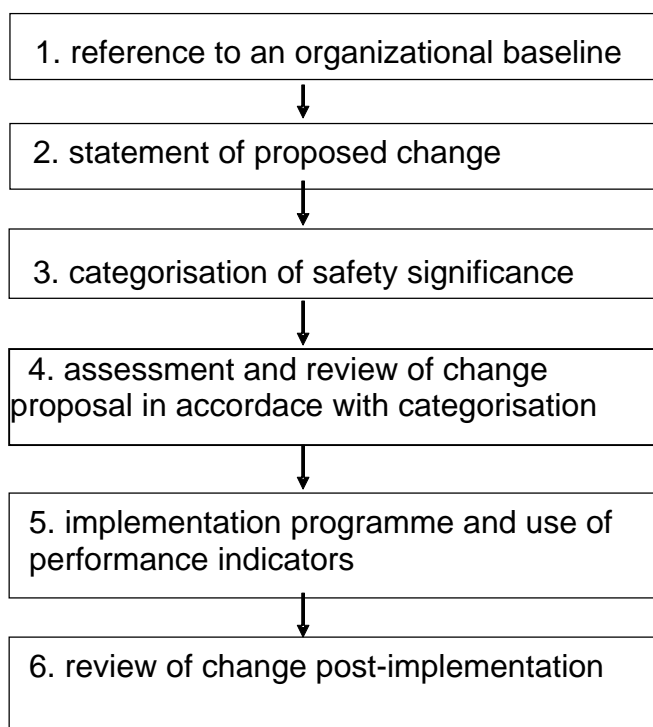


Figure 1. Model of a process for managing organizational change (adopted from NEA 2004)

The baseline assessment provides a starting point against which the proposed change to organizational structures or processes can be assessed. It is a documentation that may contain a description of current organizational structures and resources. Then, the change process starts with a statement of what the change entails, why it is introduced and what the goals of the change are. The implementation programme for the change should be prepared only after the categorisation and analysis of the proposed change has been conducted. NEA (2004) states that it is likely that most change proposals will seek to demonstrate, that there remain competent personnel to deliver safety functions, and that the responsibilities of the management are clearly

defined, and that training needs and procedural modifications have been recognised. They stress that the analysis also needs to consider the specific risks associated with the change, such as the loss of “the capability to understand the plant and to specify, manage and understand the work of the contractors” (NEA 2004, p. 13) when outsourcing functions.

The implementation programme should, according to NEA, identify those elements which need to be completed in order to enable the subsequent states of the change to proceed. These can be e.g. training, revised procedures and relocation of staff. NEA emphasises the significance of indicators for monitoring the effects of the change. These can include e.g. the following: increased working hours, reduction of “right first time” maintenance and amount of peer review comments. The rigorous change management process also includes a formal review stage. The review should draw upon and interpret the findings of the performance indicators and confirm that there have been no unexpected or undesirable outcomes. (NEA 2004.)

It is evident that managing organizational change requires a lot more phases, backtracking, explicit and implicit decisions, and challenges to be taken into account than those elements depicted in NEA’s model (cf. Clegg & Walsh 2004). NEA’s report does not describe the contents of the elements thoroughly, but when it does describe them, the focus is on the structural aspects of organizations. The baseline assessment, for example, could be more fruitful if it included other characterizations of the features of the organization such as norms, values and conceptions of the personnel than only a description of organizational structures and resources. The NEA model may be misleading in a sense that it gives the impression that the risks of the change initiatives are related mainly to the structural solutions (e.g the amount of competent persons to deliver safety functions). The literature suggests, however, that the way the change is implemented – and not the organizational solution per se – has a larger effect on the health and safety outcomes of the change (HSE 1996a; Wright 1998). We will return to these questions in Sections 5 and 6 of this report.

We are not going to list all the possible methods and approaches that exist with which to acquire the information needed in each of the seven elements in NEA’s model. As mentioned, there are plenty of them and we do not have knowledge of their validity in the nuclear industry. IAEA (2001) report offers a detailed description of some tools utilised in nuclear industry. To give you some picture of the variety of the approaches used in other domains we refer to the work of Iles and Sutherland (2001). They have summarised management tools, models and approaches that have been used for planning changes in the health care sector (Figure 2).

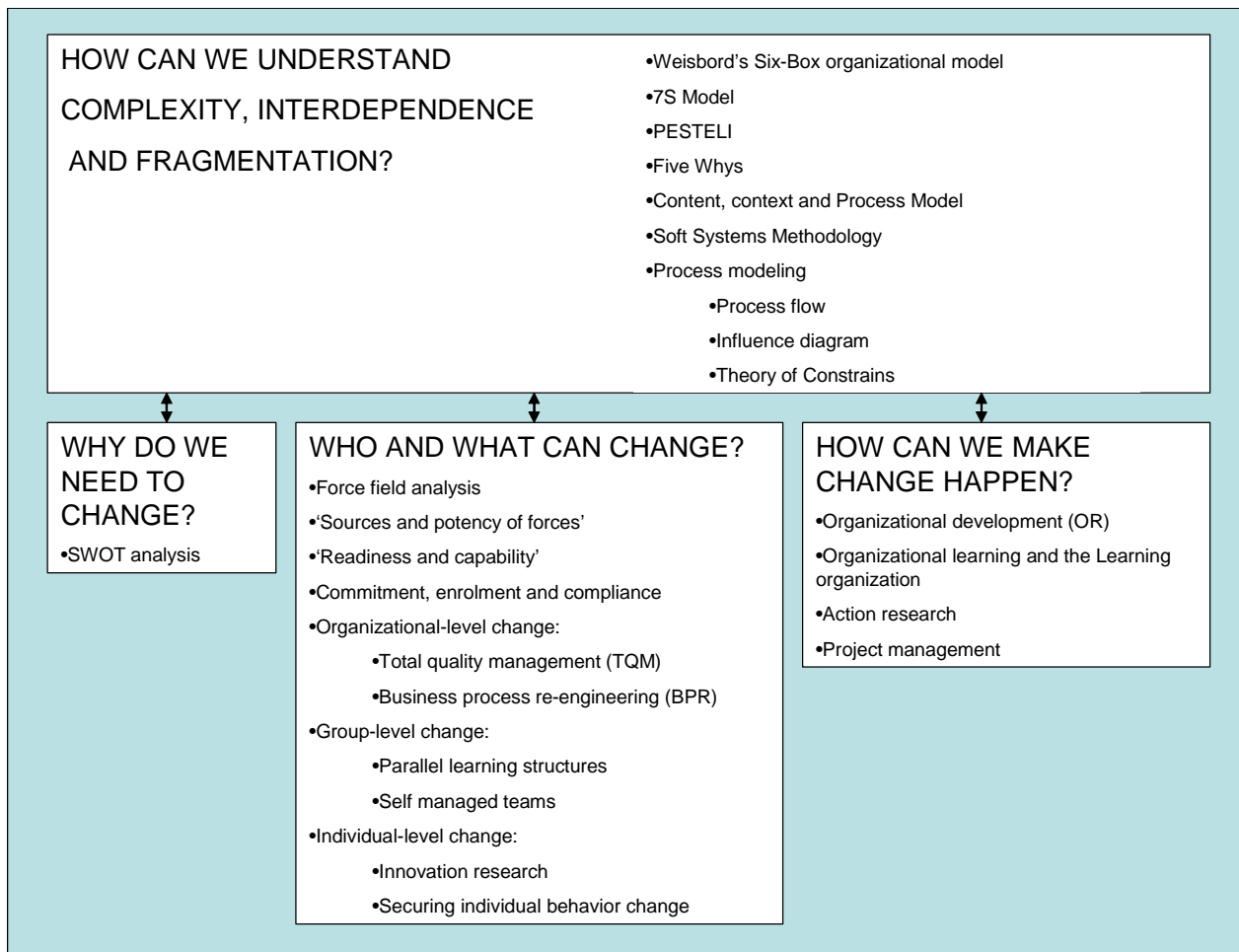


Figure 2. Examples of change management tools, models and approaches (adapted from Iles & Sutherland 2001)

Clearly, as indicated in Figure 2, a multitude of methods and theories exist to manage organizational change. In Figure 2 one of the main challenges for change management is the question “how can we understand complexity, interdependence and fragmentation” in the organization. This influences all the other choices and eventually the outcomes of the change process.

2.2 Attempts at understanding the dynamics of an organization

Both NEA (2004) and IAEA (2001) emphasise that there are also other aspects in the change that need attention (in addition to those depicted in Figure 1). The potential effects of the change on safety culture and individual workers should be considered. NEA states that an effective management of the factors that may influence e.g. staff morale, attitudes, motivation and safety culture is central. In what way can this be tackled in the change management process is little discussed by NEA or IAEA, however.

Different elements of organizations are currently recognised in the literature of change management in safety critical domains. By this we mean that both the structural aspects (e.g. staffing level, procedures, appropriateness of the tools etc.) and the cultural aspects (e.g. values, practices and morale) are discussed. Measures and tools to review the appropriateness of the aspects have been developed. In addition to that, the individual workers' ability to perform their tasks after the change is also sometimes analysed. An example of that is research concerning the fatigue effects of longer shifts. Figure 3 exemplifies the current practices that are commonly used in reviewing organizations during the change process.

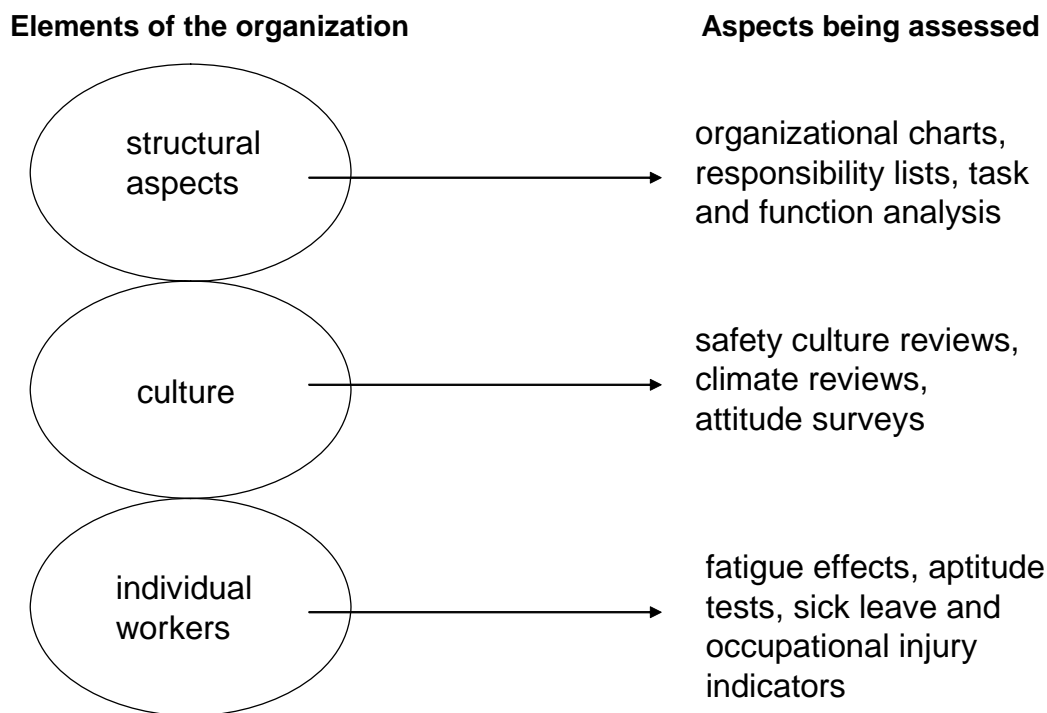


Figure 3. Typical tools that are used in organizational assessments in the nuclear industry

We see some problems in the current way of using the tools for reviewing the human and organizational factors during organizational changes. Different tools and models are used in analysing the different aspects of organizations without coherent understanding about the overall dynamics of organizational change. For example, organizational charts do not represent the entire organization nor do aptitude tests necessarily tell about the culture of the workplace. Climate reviews may indicate dissatisfaction, but its relation to structural solutions remains often unclear. The question remains, *how do the structural changes in the organization or the change process itself affect individual workers or the culture of the organization? And what are the possible safety consequences if the motivation, morale or the safety culture starts to deteriorate?*

It is clear that more understanding about issues such as morale, personnel attitudes, motivational changes and subjective interpretations of the personnel during organizational changes is needed.

Sequential models are not always reaching very well the complexity of organizational reality. They are often based on too rational and mechanistic an image of an organization (cf. point a in Dunphy's list above) which underestimates the importance of organizational cultural and personnel issues.

In this report, we aim to provide some insight into the overall dynamics of the organization in a change process. The second viewpoint to organizational changes is *the organizational culture – approach*. Organizational culture, as we conceptualize it, is a “root metaphor” for the organization. Alvesson and Berg (1992, p. 78) state that this approach “means that the cultural dimension can be found in – and not “alongside” – formal organizational structures, administrative systems, technologies, strategies” (see also Alvesson 2002, p. 25). The cultural way of studying organizations is to study “the meanings and beliefs which members of organizations assign to organizational behavior and how these assigned meanings influence the ways in which they behave themselves” (Schultz 1995, p. 5).

The purpose of introducing the concept of organizational culture is to describe from the work and organizational psychology perspective how structural changes can affect the performance of an individual - and in a long run - the performance of the entire organization. Safety management systems are one important structural aspect of the organization to consider in the change, but that is not enough. Safety management systems as such do not guarantee that the change does not have significant effects on performance. For example, Paks NPP (see Appendix A) had a certified safety management system in place.

As stated also in the IAEA report on organizational changes (safety) culture is both attitudinal as well as structural issue (IAEA 2001). Culture affects the performance of an individual, since the values, assumptions and norms concerning the right way of doing the work are largely culturally formed. But organizational culture manifests itself also in the structural elements of an organization, such as staffing level and chosen technology. We thus approach change management from the bottom up, by concentrating on how the personnel perceive the change and how they are affected by the changes, and how they in turn affect the outcome of the change process.

In the next chapter we briefly describe and then analyse actual reorganizing processes in four NPP maintenance organizations. After that, in section 5.1, we introduce a model of the organizational dynamics and their safety impacts in relation to organizational changes. The

model tries to depict our ideas of what are the possible mechanisms causing safety impacts during and after organizational changes.

3. Change processes at Nordic maintenance organizations

In this Section we depict the four cases that were used to study the effects of organizational changes on safety and effectiveness of the NPP operation. The case descriptions are based on personnel and management interviews at the plants, internal material concerning the change process e.g. organizational charts and change plans as well as data from safety and organizational culture surveys (see e.g. Reiman et al. 2005a). Most of the data was collected originally for organizational culture assessment and safety evaluation purposes. The data from the four plants thus varies in quality. The limitations of the data prevent strict comparison of the cases and their safety and other consequences.

3.1 Loviisa power plant's organization change 2002

Background of the organizational change

Five management interviews were carried out at the Loviisa power plant two years after a major reorganizing of the plant organization (Reiman et al. 2005b). Interviews addressed the goals of the change, the identified problems prior to change, the implementation of the change (both planned and realised) and the results and consequences of the change. Organizational culture assessment was carried out one year before and two years after the change in the maintenance unit (see Section 5.3).

General Manager of Loviisa NPP set up a working group in November 2001 to prepare a proposal for renewing the power plant's organization. The working group's assignment specified four key objectives: 1) Strengthening plant life management and utilising accumulated expertise, 2) making the power plant's costs comparable with other types of energy generation, recognising costs characteristic of the nuclear power plant, enhancing the efficiency of operations and maintaining competitiveness, 3) transferring information from those who were involved in constructing and commissioning the plant to the new generation, job rotation and transfer of responsibilities to younger staff, and 4) better direction of research activity funded by the plant. The working group submitted its proposal for the new organization on 17 December 2001. The Loviisa power plant's new organization formally came into effect on 1 January 2002. There was no transition stage organization. The plan was to implement practical measures by the summer holiday period of 2002.

A new organization was established based on four new units, which were built on the five groups which had existed previously. The new units had been specified in the working group’s assignment as depicted in Table 1.

Table 1. The new units and their basic tasks at Loviisa NPP

Unit	Basic task
Operating unit	Safe and optimal power generation, and acquisition of income for plant investments
Safety unit	Centralised control of nuclear power-specific operations as well as joint management and support functions
Technology unit	Taking care of long-term production conditions, production investments and the value of capital invested
Maintenance unit	Production of services required by the uninterrupted use of the plant

In addition to these four units, the new organization comprised an executive staff under the general manager (e.g. personnel affairs, payroll and accounting, communications and controller tasks) and a security unit.

The maintenance function was one of the groups most significantly reorganized. In 2001, the maintenance activities were organized into the mechanical, machine workshop, electrical, instrumentation and construction maintenance, technical design, planning and coordination and quality control sections. In 2002 the maintenance department was reorganized into five sections in order to make the distinction between operative maintenance and supportive functions more clear. The electrical and instrumentation maintenance sections were integrated. Technical design and planning were also integrated, but many of the experts were moved outside the maintenance organization into the ‘technology unit’. Quality control was moved into the ‘safety unit’. Some supportive functions such as the canteen and cleaning services were outsourced in the process.

Objectives of the organizational change

On the basis of the management interviews, there were several factors behind the organization change. One of the most important was the generation change that was under way. A large group of white-collar workers was retiring, and the experience and know-how of the older generation had to be preserved. Operational activities were also taking up the older engineers’ time. At Loviisa it was understood that an opportunity had to be provided for the older engineers “to commit matters to paper” and to transfer their expertise to younger staff. This had to be carried out, however, while maintaining the motivation of the older generation.

Before the change, the systematic recruitment of new workers had been initiated at the Loviisa power plant. In the organization it was perceived, however, that turnover among younger staff was high. It was thought that younger workers had to be given responsibility rather more quickly. The organization had been very settled for nearly twenty years. During this time only small changes had been made in the organization and the boundaries of responsibility had been set in stone. The interviews revealed that it was very difficult for young employees to penetrate this set-up.

The effectiveness of plant life management also gradually began to be a cause of some concern for the plant managers, as an application for a new operating licence approached. A production life of at least 50 years was set as an objective. At the same time, changes occurred in Fortum, and within the company ideas were formed as to how the plant's operations could be developed. On the basis of the interviews, it is apparent that these two factors – the generation change under way and the enhancement of plant life management – were closely linked to each other.

Preparation and content of the change plan

The key objectives of the change project, the unit division of the new organization and the basic tasks and managers of the new units, were determined by the power plant's senior management and an external consultant. Furthermore, it was decided to implement the project as quickly as possible. Thereafter a separate working group was set up whose task was to prepare a detailed change plan. Nine members were selected for the working group. These members included the leaders of the new units.

Although the project timetable, the new organisation's unit structure and the basic tasks and managers of the new units had been specified in the assignment, the group otherwise had great freedom of action, according to the people who worked in it. The assignment did not specify very precisely what the new units should consist of. The proposal for the distribution of different functions into the new units thus arose in the working group. According to the interviews, the starting point to defining the new organization was a listing all the power plant's present and necessary new functions, after which the grouping of the functions under the unit division specified in the assignment, began. This generated much discussion in the working group. "First there were clear issues, then there were matters of opinion and then there were 'bargaining cases' on top of everything else; as far I recall, however, we didn't have to resort to voting," said one of those interviewed. Most debate arose over the division of labour between the Technology and Maintenance units. The Table 2 describes the different subareas of the change plan.

Table 2. The subareas of the change plan at Loviisa NPP

Change subarea	Planned measures
Objectives, priorities and resourcing	Partially redefined, by emphasising e.g. plant life management, generation change and enhancing operational efficiency.
Organization structure	The most significant changes fell in this subarea. It was decided to shift to a four unit model. Functions were transferred between the different units. The idea was, among other things, to break down technology-based divisions and to build more efficient operational entities.
Operational processes and practices	The working group's proposal emphasised the importance of process-oriented operating practices. Changes in operating practices, however, remained outside the actual change project and were left for the new organization to consider.
Information systems	The organization change had no direct link with the ERP system renewal project then under way, nor was change supported by other information system projects.
Other subareas	The organization change can be considered to be linked to development projects relating to outsourcing of support functions and the development of procurement activity. The above-mentioned projects, however, had been left outside the actual organization reform.

Interviews conducted at the power plant sought an answer to why organization change had been selected as the way to achieve the set objectives. The objectives had been formulated so that they could also, at least in principle, have been attained without changing the structure of the organisation. On the basis of the responses, the key reason was considered to be a certain kind of "opposition to stagnation", in other words a perceived need to change established operating practices in a situation where structures were seen to form a barrier to change. In addition, the strengthening of plant life management and the commitment of young employees were considered to require, among other things, a new division of labour and job rotation, which would be difficult to implement without organizational changes.

Another factor that occupied the researchers was the exclusion of process development from the actual change project. According to those interviewed, this was decided upon because simultaneously changing the organization structure and operating practices was considered a too demanding and risky step. Motivation factors also had an impact on the issue. Those interviewed supposed that people commit themselves to new operating practices better if they are personally involved in defining them. That's why it was decided to leave the definition and development of operating practices to the responsibility of the new organization.

Implementation and results of the change

The activities of the working group responsible for planning the organization change ended on the publication of the proposal at the end of 2001. An external consultant was used to introduce the new organization. The consultant did not, however, participate in the working group's activities nor was he involved in implementing the changes. Implementing the change remained in practice primarily the responsibility of the new units' managers and their chosen subordinates. The power plant's management group monitored the project's progress. Other, separate groups were apparently not set up to direct the implementation of the change. The interviews provided partly contradictory information about this, however.

The organization has an enormous number of different tasks, which had to be distributed between the personnel. At the same time, an effort was made to ensure that no essential tasks were lost. An individual could therefore give up a task for which he was responsible only when a new owner had been found for it. This process was assisted by the use of task transfer forms, for example. The transfer of tasks was reported to have gone quite well within the units. A significant factor in the success of task transfers was how well the individuals involved knew each other. One interviewee reported that it proved difficult, however, to give up the old organization's responsibilities – particularly if the individual concerned was involved in various projects. This contributed to slowing the final implementation of the changes.

When the project was being prepared it was considered that the transition stage would not last long. By summer 2002 the facilities and rooms had been assigned. Similarly the task transfer timetable had been finalised. It was not possible to keep to the original timetable, however. The transfer of tasks began in 2002 and continued throughout the whole of 2003. There were still few individual measures to be performed in spring 2004.

In April 2003, an evaluation meeting was held at the power plant to consider the results of the change project. In summary it can be said that insufficient attention had been paid to operational processes. The reform's further measures had also slowed significantly. Key problems that followed on from these included: poor communication over unit boundaries, unclear job descriptions, slow decision-making and slow progress on matters in general. The meeting found that the further development of the organization ought to be based on the identification, modelling and documentation of operational processes. Interviews conducted at the power plant in spring 2004 revealed the most important topical challenges to be, among others, the

development of guidelines, adjusting the division of work between the Technology and Maintenance units, and matters relating to supporting the transfer of expertise.

The technical objective set for the organization change had, as a rule, been achieved in spring 2004: the new units and groups had begun their work under new leaders. From the researchers' standpoint, however, the most interesting aspect was to clarify the kind of results that had been achieved relative to the original objectives set for the project. In relation to plant life management, significant progress had been made, according to those interviewed. More responsible jobs and vacancies had also been arranged for younger employees. In terms of transfer of information and tasks, on the other hand, the impacts were perceived to be negative. While young employees had been appointed to new positions in the organization, a number of older employees felt somehow marginalised. They felt that there was no desire to utilise their experience, and as a result their motivation to share knowledge was weak. This can be considered the most important challenge in follow-up measures to the organization change; how to maintain the older employees sense of personal responsibility and a feeling that they are doing an important work. These interview findings were validated by the organizational culture survey, which is discussed in the Section 5.3.

3.2 Organizational change at Oskarshamn nuclear power plant (OKG) maintenance

Five in-depth interviews were conducted in 2005. Four of the interviewees were part of the various management functions of the maintenance department. Three of these four persons were part of the small group who put the change process in concrete form. The fifth person was a member of the safety department. The interviews addressed various aspects of the organizational change. Also the internal documents and surveys of OKG were utilised in the analysis.

Background and some observations from the interviews

The financial pressures in the end of the 90's, primarily due to the low energy price combined with the increased nuclear taxes, led the managing board of directors of OKG to see over the costs of the power plants. The conclusion was that it was possible to reduce the costs of running the plant. The CEO of OKG thus initiated measures to reduce these costs. One of the measures was to review the number of employees. The change was done in three major steps, in which the reorganization of the maintenance department described below was a second step. The first step concerned the department of general services (department G), and the third and final step concerned the remaining parts of the organization.

The preparation of the change concerning the maintenance department was initiated when the CEO gave the person responsible of the change for step one (the head of department G, who quite soon to become the head of department U, maintenance), the responsibility to carry out the change for step two. The head of department U selected the persons for the working group that developed a pilot study of the proposed change. During this period the group did not “go public” with the reasons for the meetings, this in order to not worry the organization with rumours, before the strategy of the change/pilot study were decided. After the overall planning for the change was decided, information about the change was released. Around this time the heads for the different sub departments in the maintenance department were employed by the head of department U. This managerial group enlarged upon the change plan further. At the same time the personnel on the former unit specific maintenance departments got notice to quit, and were requested to apply for the newly formed jobs in the new department. During the two-year period after the implementation of the new maintenance organization the jobs decreased from approximately 290 to 220.

One interesting observation done during the interviews was that the perceptions of the primary goals of the reorganization tended to differ slightly the more the (management) person was alienated from the first working group, and also when the person was employed after the implementation took place. I.e. persons directly involved with the strategy discussions of the change only stressed the goal of reduced costs, primarily via reduced personnel and saw the other benefits more as consequences of the primary goal. Management personnel that were not part of the group making the strategies and who were hired some time after the change was implemented, saw the benefits of, for example, uniform work practices and free movement of personnel between the three power plants at OKG as the prime objective of the change. In this case personal reductions and thus reduced costs were more seen as a consequence of the increased efficiency. From the interviews it also turned out that risk analyses were performed.

Description of the implemented change

The maintenance organization at OKG was previously organized under each power plant unit. The structure of the maintenance organization was also different at each unit, for example function- (reactor, turbine, etc.) and subject oriented (mechanical, electrical, etc). To develop and make the maintenance activities more effective, and also to obey the increased demands for savings, the maintenance at OKG was centralized by the year 2000.

The new organization was created by functionally constructing the maintenance department around four smaller maintenance departments, yet with a substantial element of process orientation.

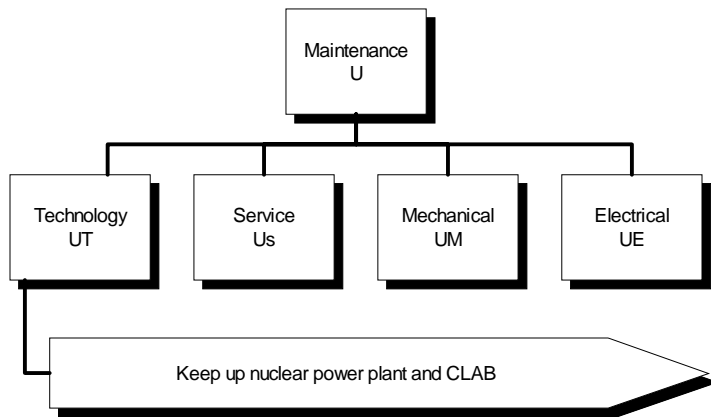


Figure 4. The changed maintenance organization at OKG.

An overarching description of the new maintenance organization (see Figure 4):

- o The department of technology, UT, is intended to work with overarching techniques, strategies, and administrative systems. The manager at UT was also a process leader for the process "keep up the nuclear power plant and CLAB¹".
- o The service department, US, is intended to provide the service functions which are common for the maintenance.
- o The department of mechanics, UM, is responsible for the mechanical maintenance.
- o The department of electricity and instruments is responsible for the maintenance of electricity and instrumentation.

The degree of process orientation gradually increased, and the process leader initially coordinated the processes to avoid mismatches between the different functions. Improvement teams were appointed to develop the processes.

The savings of the organizational change were primarily linked to a more effective use of internal and external resources. This made it possible, and was a prerequisite, for the reduction of the personnel. It was also estimated that the organizational change would give OKG a number of possibilities to influence the reactor safety in a positive way, among other things by introducing uniform working procedures and also to increase and create redundant competences.

¹ CLAB means the Central interim storage facility for spent nuclear fuel.

Concluding remarks about risk analysis concerning the change management at OKG

The trend at OKG has been to extend both the scope and the formality of the risk analysis. One example deals with the second and third step described above where a formal risk analysis (safety evaluation) was conducted. This safety evaluation was, however, primarily based on the personal experience of the persons conducting the safety evaluation.

In the latest reorganization conducted on OKG the objective was to separate CLAB from OKG to SKB. Before the implementation, and during the planning of the change, risk analysis were performed which primarily emphasized the risks with the project as such.

The safety evaluation, which is part used the system group perspective (Andersson and Rollenhagen 2003), did follow a fairly clear process which for example did cover a pre set of questions based upon Rollenhagen and Kahlbom (2001). These questions were considered when the three more general questions below were elaborated on, even though the emphasis lay on the first of these questions:

- Will the organizational change, under the condition that it is implemented and that the staff has got a positive attitude towards the change, lead to an acceptable safety level?
- Is the process for change for the implementation such that the objective with the organizational change will be fulfilled?
- Is there a plan for the implementation and also measurement tools that will identify, evaluate, and act regarding “threats” toward the objectives

The results were also discussed in the light of the impact of influence of safety, and also criteria in SKIFS.

3.3 Changes at Forsmark nuclear power plant (FKA) maintenance

Brief history of the maintenance organisation

Forsmark has, over the years, tried several different organizational structures for their maintenance organization. Until 1982, a central maintenance organization was in place, subdivided into mechanical-, electrical- and instrumentation maintenance. In 1982 reorganization was launched so that each of the 3 individual power stations received their own maintenance organization. According to the interviews with personnel employed at this time, the benefit of this reorganization was clearly shown in terms of clear responsibilities, an efficient local communication and decision structure and a sense of ownership among the maintenance

personnel. In order to adapt to retrofit and modernisation plans, the maintenance organizations were again changed in 1994: an entrepreneurial relationship among the actors was introduced. Maintenance, at each site, was organized in reactor- and turbine sections that had the responsibility for the technical development and maintenance at each station. Specific maintenance disciplines were perceived as subcontractors coordinated by the reactor- and turbine sections. In the years to follow some changes were made in the structure, but not major ones, and the strategy of separate maintenance organizations at each station was maintained until 2001. Process analysis of maintenance has been conducted since 1996 and the output of these efforts became a major input for the reorganization 2001.

Reorganization in 2001

The background for the major reorganization of maintenance that begun in 2001 is to be found in the deregulation of the electricity market in Sweden – in the first years after the deregulation there was a sharp decrease in the prices for electricity. The changes in the maintenance organization were a search for more efficient resource optimization. Several changes were made, most importantly: (1) The individual maintenance units at each station were brought together to form one single maintenance organization; (2) A matrix organization structure was implemented for the maintenance unit, (3) At each station, order functions were developed to support dialogues with the four business areas found at the central maintenance unit (business areas: operative maintenance, projects, analysis and montage), (4) Some services, that previously was in-house operated, had already been outsourced in 2000 (building service, cleaning, transportation services etc.). Risk analysis of the change was done as SKI demanded.

The four business areas controlled and implemented operative maintenance projects that were ordered from the stations at the site. Responsibility for the execution of various maintenance projects was, in the new organization, separated from the responsibility for the maintenance resources. As usually in matrix organizations the operative personnel had several “bosses”. A technician could conduct work to several business areas under the manager from that area. The line manager allocated the technician to the particular business area that needed resources.

Several follow-up studies and evaluations (with several different methods and also carried out by independent evaluators) conducted after 2001 gave evidence of experienced problems in the maintenance organisation. These included e.g. yearly safety culture survey which indicated a decline after the change. Among the problems encountered were the following: difficulties for many of the employees to cope with the matrix structure and the roles that were associated with

the new organization, coordination and communication difficulties, and conflicts over resources, vagueness regarding responsibilities, and negative working climate.

Due to e.g. the above mentioned problems, it was decided to change some aspects of the organization in December 2003 – one of the most important changes was to replace the matrix organization with a more traditional line organization: the former business areas disappeared so that maintenance is managed directly by the maintenance sections. The planning function was also strengthened in order to coordinate the activities. The current maintenance organization is led by a maintenance manager that has seven sections (electrical, mechanical, control equipment, installation, planning, technology, protection).

3.4 Organizing of maintenance at Olkiluoto nuclear power plant (TVO)

Olkiluoto NPP has conducted many minor changes in its maintenance organization during the years of its operation. One of the major changes occurred over ten years ago. In 1994 TVO united maintenance and operations under one umbrella called “operation maintenance”. At the same time, numerous other changes to the organizational practices and tools were made. For example, a system of equipment responsibility areas was taken into use to organize the maintenance work. Furthermore, a comprehensive new information system was taken into use to organize the work, store plant-related information and plan the maintenance activities on a short and long term basis.

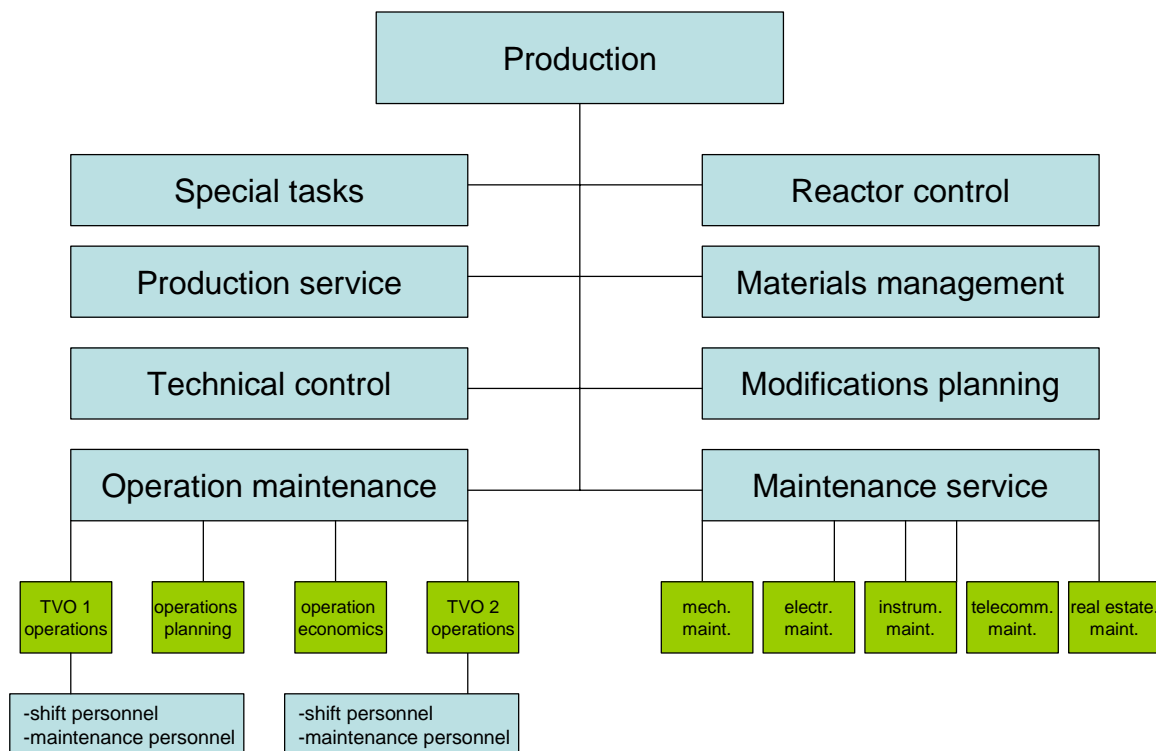


Figure 5. The production department of TVO from 1994 to 1996.

The system of equipment responsibility means that the foreman or the group manager "owns" the particular equipment group and plans e.g. the program of preventive maintenance and budget for the machinery. The owner of the equipment plans all the maintenance activities conducted for the corresponding equipment, irrespective of the type of maintenance (electrical, mechanical, instrumentation) required. The owner utilizes experts of the other fields to accomplish this. For example a valve can include an actuation device and thus electrical and instrumentation work, but the owner of the valve can be from the mechanical maintenance. The owner also analyses operational data concerning the machinery, and makes inferences about the appropriateness of the schedule for preventive maintenance operations. The owner updates the plant information system (LATU) with the data concerning his area.

Maintenance expert described the old organizational structure:

In 94 when the change was made a part of maintenance was transferred under operations. Two times eight [persons] at both units, of course electrical and instrumentation technicians more because there are plenty of testings and verifications. In 2000 electrical and I&C maintenance were combined, in a way the personnel from operations were withdrawn, because there was the problem that there was the instrumentation maintenance there, and the responsibilities got too spread out, it was wanted to put these groups together. ... in 94 when maintenance was put under operations, the goal was to increase cooperation between the control room and maintenance personnel, and we succeeded in a way in combining the circulation lists ... the aim was that the maintenance personnel under operations would be 100 percent employed, in preventive maintenance. But the maintenance service unit then, and the responsibilities there, those broke down a bit.

Even though the change happened about ten years ago, it is still fresh in many employees' minds and comments related to the change came up in the interviews conducted at the maintenance department spontaneously (see Reiman et al. 2005a) and also in other informal conversations with personnel from different departments of the power plant. What is noteworthy about these comments is that some consider the organizational change a failure, some if not a success at least a quite good organization. Further, the reasons and goals that are attributed to the change varied also, partly depending on whether or not the personnel considered the change a failure or not. Many of the persons who criticised the outcome of the change process saw it as having goals related more to the power relations of the plant than to improving safety or organizational performance.

The current 2005 organization comprises eight departments: 'Operation' responsible for the operation and maintenance of units OL1 and OL2, 'Project' responsible for the construction of

the fifth NPP in Finland (OL3), ‘Power Plant Engineering’, ‘Nuclear Engineering’, ‘Finance’, ‘CSR and Communications’, ‘Legal Affairs’ and ‘Corporate resources’. Approximately 120 employees work with issues related to maintenance in the ‘Operation’ department at two offices: The office of mechanical maintenance and the office of electrical and I&C maintenance. The offices consist of a number of small groups with a group manager, foremen and technicians. The groups are spatially dispersed, some people working in the workshops and some at the plant itself. Further, some groups have a clear division between the technicians working in OL1 and OL2. Some groups are responsible for the maintenance work at the plant site outside the main buildings (e.g. the switchyard). Thus, the logic of organizing the work resembles the 1994 model in practice. The largest difference is that no maintenance personnel are working directly under the shift supervisor.

Although mainly considered as good, main dispute in the current organizational structure was caused by the separation of personnel into unit 1, unit 2 and the repair shop. Some considered it a good thing, whereas some disagreed:

“In this organization we have the problem that we have guys from the unit 1 and guys from unit 2, and then we have the guys at the repair shop, and that causes that the responsibilities, I mean that it has formed during these 25 years, it is hard to get people from unit 1 to unit 2 or the other way round. It causes a lot of idling when there’s work at one unit but not at another. And also the repair shop has its own clique.”

On the other hand, plenty of benefits of this arrangement were also pointed out, e.g. the avoidance of “wrong unit” errors (work conducted at wrong plant unit) and a better chance to concentrate on certain specific equipment.

4. General findings

4.1 Comparison with the NEA change management process

The four NPP maintenance reorganising cases had both similarities and differences. The managers at all the plants clearly initiated the change process in question. By this we mean that all the changes were planned organizational changes, not organizational drifting. Still, the change management process did not in all the cases follow the guidelines set by e.g. NEA (see Section 2.1).

The change management process at OKG did follow the NEA on an overall level. At Loviisa NPP, there was no clear change management philosophy present, the change was not projected. Baseline data was assumed to be present based on the existing data about the personnel and structure of the organization. This applies also to FKA and OKG. At OKG several analyses were performed in order to chart the current maintenance staffing with regards to age, formal education, competencies and areas of work. In most cases, the change was heavily management driven, and statement of the change was given to the personnel quite late in the process. Some kind of an implementation plan was prepared in all the cases. The plans included at least the schedule, responsibilities and formal competence requirements. To the best of our knowledge, methods for supporting the actual change of working practices were little included in the implementation plans. At Loviisa e.g., implementing the change remained in practice primarily the responsibility of the new units' managers and their chosen subordinates.

At Loviisa the most defining characteristic of the change was the fast time table of the planning and implementation. This was partly due to the fact that the Finnish regulator currently does not explicitly require risk assessments before organizational changes. At both FKA and OKG, formal risk assessment was done as required by SKI. During the change, at OKG for example, several analyses and reviews were performed internally (in the change project), and externally (by the technical department specialized in safety reviews and by the safety department). At Loviisa, a review of change was made in the management board one year after the reorganization. At OKG, after the implementation, reviews were mostly performed by measuring economical results, but also by performing different surveys. Frequent contacts between the personnel and managers were also mentioned as important ways of getting information. At FKA several indicators (efficiency, safety, costs) were used after the change together with several independent assessments and safety culture questionnaires.

As described in the Section 3, all the changes faced plenty of obstacles. They were thus learning opportunities for the future change projects. For example OKG has described a detailed process to be used in managing organizational changes in the future. A comprehensive description of the process for organizational change management as performed by OKG in the present situation is presented in Table 3 below. The description was derived from the internal OKG-document that gives the account for the realization plan regarding the new organization for CLAB.

When comparing the process today (for CLAB) compared with the process used for the maintenance change, the process is probably not that different on a general level. The depth for some of the steps in the process has, however, probably been increased.

Table 3. process for organizational change management as performed by OKG

Activity plan	Time plan (time before implementation)
Development of document for controlling the field of activities control (describes the objective of the change)	6,5 months
Appointing the working group	6,5 months
Union related discussions – information	6 months
Early notification to the regulatory body (SKI)	6 months
Analysis of staffing	5,5 months
Documenting the areas of competencies	5,5 months
Distributing the areas of competencies/scope of works (within the proposed organizational structure)	5,5 months
Union related discussions – negotiation	5,5 months
Perform risk analysis	5,5 months
Internal advertisements – new management positions	5,5 months
Description of the management system	5 months
Union related discussions – information regarding suggestions for managers	5 months
Start the employee-process	4,5 months
Union related discussions – information regarding the appointment of managers	4,5 months
Distributing the instructions to the different fields of activities	4,5 months
Presentation of the analysis of staffing	4,5 months
Information meetings in small groups	4,5 months
Decisions regarding staffing	4 months
Structuring the instructions to the different fields of activities	3,5 months
Safety evaluation with regard to nuclear safety	3 months
Primary safety review	2,5 months
Safety review performed by the safety department (fristående säkerhetsgranskning)	2 months
Announcement to the regulatory body (SKI)	1,5 months
Measures of improvement (based upon for example risk analysis, safety evaluation, and safety reviews)	1,5 months
Implementation of new organization	

4.2 Why maintenance organizations have been reorganized

Even though the changes in the maintenance units were planned and they all had written implementation plans, there existed various interpretations about the change and its consequences in each case. The following goals of the change initiatives were raised by the

management and maintenance personnel (see Table 4). From the table it can be observed that cost reduction, enhancement of the efficiency of maintenance activities, and maintaining and developing competence were identified as goals in all the changes reviewed in this article. Plenty of other goals were also identified. What is interesting to note is that many of these goals deal with cultural issues such as communication, status, personnel issues and stagnation (“waking up” the organization). Some of these goals were explicit, some implicit, but they all affected the way the change was carried out and eventually the outcomes of the change process. Despite the prevalence of “soft” goals, few organizational and personnel development methods were used in the cases though.

Table 4. The identified goals of the change initiatives at the maintenance organizations

GOALS of the maintenance change	Plants
reduce costs	all four
maintaining and developing competence	all four
enhance the efficiency of the maintenance	all four
maintain nuclear safety in the long term	three or four
enhance the availability of the maintenance personnel to different units or tasks	three or four
enhance the status and role of maintenance	two
standardise work procedures in maintenance	two
enhance coordination between operations, technical and maintenance	two
to fix a bad previous reorganization	two
enhance climate and personnel issues, such as increasing working climate, getting rid of troublesome personnel, getting more development oriented people into supervisory positions	two
change of roles and responsibilities between operations, maintenance and technical departments	two
provide career opportunities for young people	two
waking up of the organisation	two
Give the personnel more responsibility	two
Increase cooperation with operations and maintenance	one
enhance the status and role of technical department	one
enhance the status and role of operations	one
separate nuclear power specific costs	one

We also found evidence that many of the identified goals in Table 4 were raised afterwards as explanations for the change. The interpretations of people concerning the “real” goals of the change also differed quite a lot within the maintenance units.

Clegg and Walsh (2004) speak of “latent functions”, by which they mean the other goals of the change initiative than the primary and explicit goals to improve the organizational performance. They write: “It is oversimplistic just to focus on the apparent manifest goals, especially as stated in some change programme and investment case. Other goals will also be present and these need recognition and attention.” (Clegg & Walsh 2004, p. 231) Change initiatives thus always involve multiple explicit as well as implicit goals, and more goals will be attributed to them by the employees after the change. This attribution of reasons for change is done depending on the consequences of the change initiative and on the amount of information the personnel have concerning the “real” goals of the change. If the change leads to negative consequences among the personnel (such as increased workload), more negative goals will be attributed to the change (such as that the goal of the change was to increase profits by reducing personnel). Also if the real goals of the change remain vague or are not communicated to the personnel, they attribute goals to the change initiative based on their perceptions, knowledge and rumours.

Next we will present our cultural framework for understanding organizational change and discuss the cases in the light of this cultural view of an organizational change. In this paper we do not consider how the changes have reflected to e.g. the number of events and incidents at the corresponding plants. Instead we try to illustrate how the structural changes can affect the culture and performance of the individuals at the organization in the short term or the long term.

5. The cultural effects of change in maintenance organizations

5.1 Model of an organization

We have constructed a simplified model of an organization consisting of three elements; organizational structure, organizational culture and individual person. These elements reflect the typical issues that are considered in assessments of organizational changes. The elements are depicted in Figure 6 together with dimensions that we have found to have special relevance in change situations (see e.g. Reiman et al. 2005a, 2005b; Rollenhagen 2005). The elements are not independent. On the contrary, they are overlapping and interrelated dimensions with culture combining and facilitating the interaction between structure and individual. In Figure 6 we have also tried to give some examples of the potential safety impacts of the different elements after an organizational change.

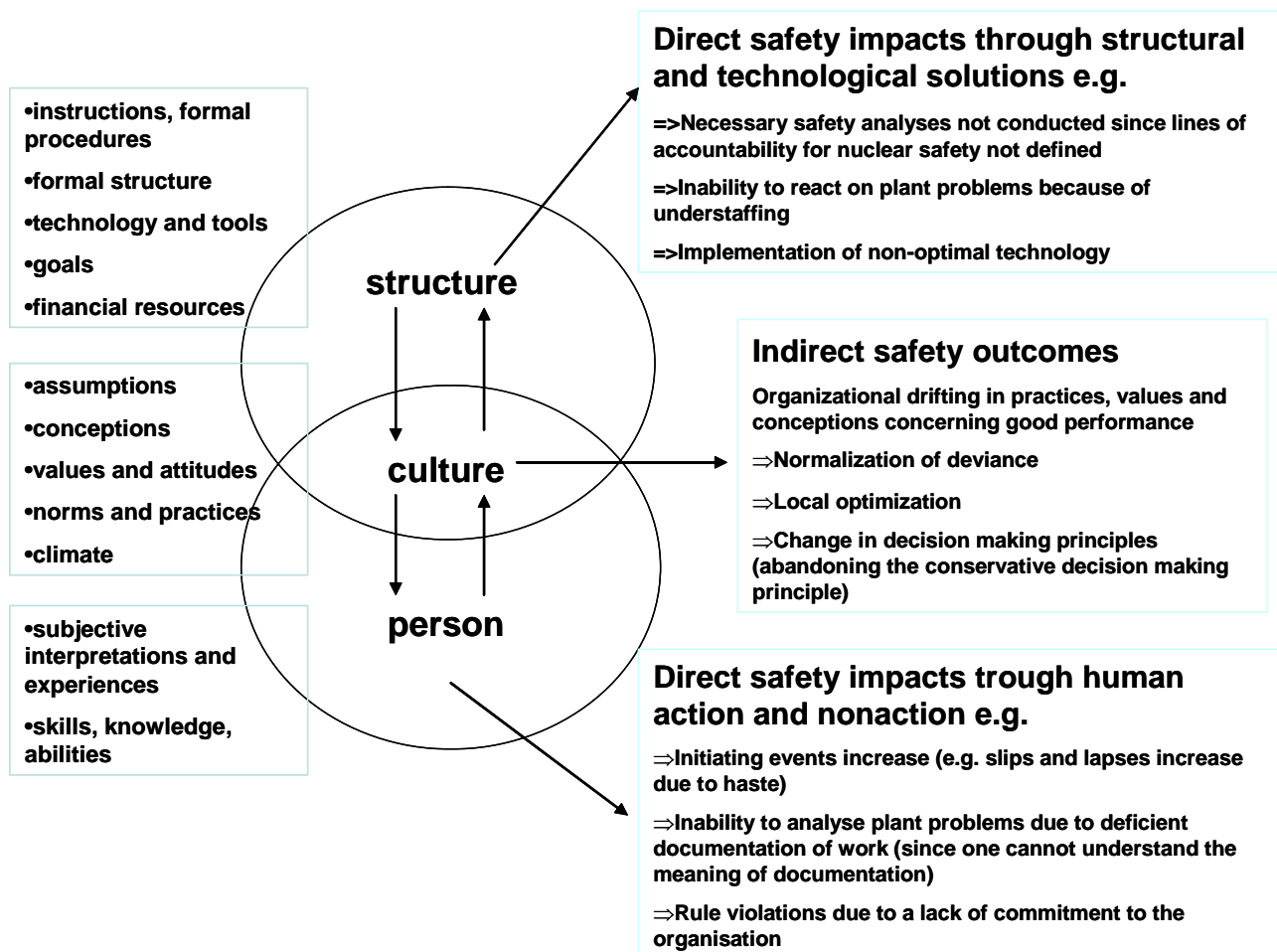


Figure 6. The elements of organization, their interrelations and the possible safety effects in organizational change

We conceptualize an organization as consisting of three elements: (1) structure including formal procedures, technology, tools and resources of the organization, (2) culture consisting of assumptions and conceptions concerning the work and the organization, values, norms and practices, and (3) individual person, including his/her subjective interpretations and experiences, and his/her knowledge, skills and abilities.

We propose that in order to understand the effects of organizational changes on the organizational effectiveness and safety, we have to understand the overall dynamics of the organization including the interactions between organizational structure, culture and individual persons.

5.2 How does reorganizing affect performance

We argue that **organizational changes (both incremental changes and major reorganizations) are a potential safety risk especially since they have an effect of the above mentioned dimensions and their interrelations that is hard to anticipate before the change is implemented.** For example, a new organizational structure can increase the personnel's work stress or decrease their sense of control over their work due to e.g. new competence requirements, change in the division of labour, changes in the resources available or the introduction of solutions that are considered against the cultural norms in the organization. Also, complex organizational structure can "hide" responsibility and safety significance of one's own work, further reducing the perceived meaningfulness of one's own work and sense of personal responsibility over it. Changes are interpreted and experienced in the light of the existing practices and culture, and changes in the psychological factors can lead to changes in performance. This performance in turn can affect the organizational culture for better or for worse. This means that some organizational structure that has worked well in another plant or another industry can be interpreted and experienced totally differently in the existing culture. This has to be taken into account when borrowing solutions from another industries or power plants.

How then to measure and anticipate the subjective experiences of the personnel? We have utilised both interviews and surveys and have found four dimensions of special relevance here (see Reiman et al. 2005a,b): *Knowledge of expectations* (role and goal clarity, and degree to which people feel that goals, tasks and responsibilities are well defined), *meaningfulness of the work* (the content and variation of the tasks and the feeling that the work is important and leads to personal development), *experienced control over one's own work* (the degree of personal sense of coping with the tasks and the demands that they set), and *sense of personal responsibility*

(internal state of motivation and a feeling of being personally accountable for the results of one's actions). These psychological factors can be considered as prerequisites for motivating and effective work and are thus of special relevance in terms of the effects of organizational change on human performance.

These dimensions seem to be sensitive to change and thus reflect the current “reality” of the employees, not some official rules of conduct. The subjective interpretations about the organization and one’s own work may change very quickly when changes in the organization are introduced. This is why these dimensions offer a good indicator of the possibly deteriorating performance and safety culture. Organizational culture changes more slowly, only when the subjective experiences become commonly shared and a part of the everyday work.

One should bear in mind that these conceptions are subjective and thus not necessarily corresponding totally with “objective” reality. This does not mean that they cannot lead to objective outcomes. Falsely experienced control (without actual control) can actually be more dangerous than correctly experienced lack of control. Same thing is true with e.g. goal clarity, if it is based on a false image of the goals of one’s own work. The most important point is that these conceptions are “real” to the employees, whatever the “actual” content, significance and organizing of their work, or whatever their “actual” level of competence or responsibility in carrying out their tasks.

The so called resistance to change on the individual level is usually a result of a mismatch between the dimensions of the organization. For example, the current norms concerning the safety of operations might not in line with the new organizational solutions. In this case it is sensible that the personnel try to resist changes that they interpret as endangering nuclear safety. Also, changes in structure may create ambiguity about who’s responsible for things and what is expected of me. These changes may also create additional work, thus lowering the sense of control of the worker. In all these cases, resistance to change is a natural phenomenon and can only be overcome by taking all the three dimensions of the organization into account (Figure 6).

Bolman and Deal (2003, p. 393) argue that a major organizational change generates four categories of issues. First, it affects individual ability to feel effective, valued, and in control. Second, change disrupts existing patterns of roles and relationships, producing confusion and uncertainty. Third, change creates conflict between winners and loser – those who benefit from the new direction and those who do not. Fourth, change creates loss of meaning for recipients rather than owners of the change.

Change undermines existing structural arrangements such as roles, responsibilities and authority structures, and thus creates ambiguity, confusion and distrust (Bolman & Deal 2003, p. 374). Change also invariably creates some conflict in the organization (Bolman & Deal 2003, p. 376). Crucial issue in terms of the outcome of the change is how this conflict is handled, is it disregarded until it finally outbursts in more harmful way, or is it dealt with behind the scenes and not face-to-face, or is it dealt in the open where personnel have a chance to show their feelings and worries concerning the change whether they stem from the safety consequences of the change or from loss of power or from the fear of becoming obsolete in the new organization. Some conflict stems from the different interpretations of the change process (goals, hidden agendas, success) which may in some cases be unfounded. Discussion and communication with the personnel would be beneficial in these situations. Bordia et al. (2004b, p. 358) write that “communication not only reduces uncertainty but also increases a sense of control over personal circumstances related to change”.

Uncertainty is one of the most commonly reported psychological states in the context of organizational change (Bordia et al. 2004a, 2004b; Bolman & Deal 2003). It is also one of the major sources of stress and reduced employee well-being during the change (Ashford 1988; Bordia et al. 2004b). Bordia et al. (2004a) differentiate three types of uncertainty, strategic (reasons for change, future direction of the organization), structural (changes to the inner workings of the organization, such as reporting structures and functions of different work units) and job-related uncertainty (uncertainty regarding e.g. job security, promotion opportunities, changes to the work role). The different types of uncertainty can be hypothesized to affect the psychological states in Figure 6 also differently. For example, strategic and structural uncertainty can affect more the knowledge of expectations, whereas job-related uncertainty can affect also sense of control. All these can also have an effect on the sense of responsibility and meaningfulness of work.

In Figure 6 there are also depicted some examples of the possible safety consequences of the three elements of the organization. Structural changes can have direct safety effects, e.g. if non-optimal technology is implemented or the responsibility areas are defined in a manner that leaves some important functions out. Further, understaffing or quitting of some tasks that were considered unnecessary may cause safety problems if not carefully analysed. Changes also affect the individual persons, and their performance in turn can have direct safety effects, e.g. due to increase in haste, lack of commitment to the organization or outdated skills. Changes in organizational culture are also important to take into account. Culture can have direct safety

effects through such phenomena as normalization of deviance (something deviant becomes a norm), local optimization (subgroups optimize their own practices without considering the entire organization) or change in the norms and principles of decision making at the organization. Further, culture has an indirect effect of safety: In time, changes in culture affect the individual person and the structural elements. For example, if the norm of conservative decision making is abandoned in the culture, this might influence the next decision about a technical modification.

5.3. Evidence from the Nordic NPPs

Measure of the characteristics of the Loviisa maintenance culture before and after the change

The Loviisa maintenance culture was first measured and assessed in 2001 before the major restructuring of the maintenance activities at the plant in 2002. Some non-critical functions were outsourced, electrical and I&C maintenance were combined, and a new department was formed which concentrated on non-critical tasks such as real estate services and heating, plumbing, ventilation and electrical installation.

Development project was carried out with the maintenance personnel during the year 2002 (Oedewald & Reiman 2003b). Discussions with the personnel suggested that the reorganization was experienced as frustrating. The uncertainty about the goals of the change and about the possible new requirements for the maintenance groups was evident. Change happened so quickly that it took some time to adapt to and deal with the new situation.

Maintenance culture was re-measured two years after the change. At that time the initial shock caused by the change was somewhat subsided. The results of re-measurement were compared to the results of the first measurement. Significant changes were noted in the **values** perceived as being endorsed in the organization. Almost all individual values are now felt as being endorsed more than before. Especially dramatic change was noted in the values that were very low in the first measurement, e.g. the mean score of “initiative” had improved from 3.3 to 4.1, “open communication” had improved from 2.9 to 4.0 and “questioning old practices” from 2.9 to 3.6. The only values that had not changed significantly in the terms of mean scores were values related to financial issues.

Conceptions concerning one’s own work were in many respects same as before the reorganization. Job satisfaction was quite good, and the job was experienced as meaningful. The working climate in one’s own work group had gotten somewhat better (from 3.5 to 4.3). Work stress had risen slightly (from 3.3 to 3.6) but the original mean score was very low. The goals of one’s own work were also seen more clearly (from 3.9 to 4.3). These findings were a somewhat

surprising for the personnel and the management, since the change had been labelled by the personnel as having been difficult and burdensome. Figure 7 depicts the change in conceptions concerning one's own work in 2001 and in 2004 measures.

There were thus significant changes in the organization in terms of perceived values and also in terms of individual work motivation and working climate. Nevertheless, the core task section, which measures conceptions concerning the maintenance work, gave implications of some new worries and tensions among the personnel. For example, question “economy contradicts with safety” received a higher mean score than three years before (from 3.7 to 4.1). What was interesting in the core task section was that question “bureaucracy is needed in order to guarantee safety” was increased from the mean score of 3.8 to 4.3 in the remeasure. Before the organizational change, the amount of bureaucracy was one of the major concerns among the personnel. After the reorganization the personnel felt that bureaucracy and the hierarchical decision making are needed (more than they were utilised in the new organization) in a nuclear power plant in order to guarantee safety. Furthermore, a couple of the questions received quite high standard deviations indicating a lack of agreement in the culture: “rules relieve of personal responsibility” and “economy contradicts with safety”.

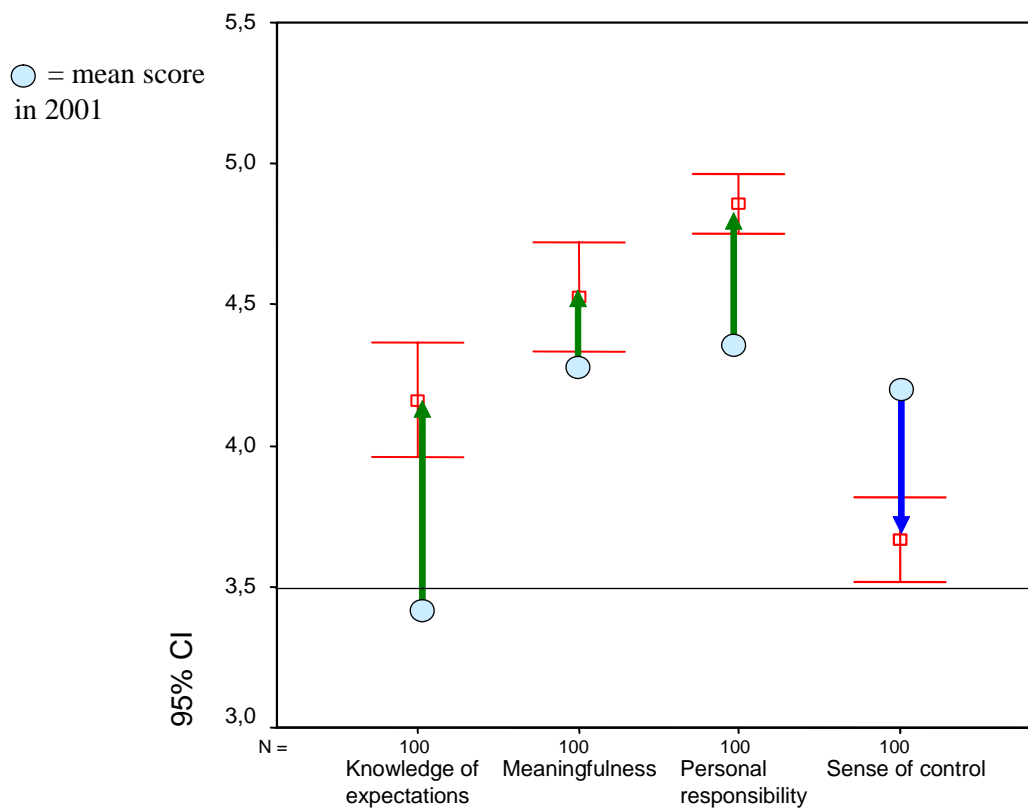


Figure 7. Conceptions concerning one's own work in 2001 and in 2004. The response scale was from 1 (totally disagree) to 6 (totally agree).

The results implied that on the one hand, the reorganization was criticized (“it broke down a good well functioning entity”) and experienced as very stressful. On the other hand some issues had clearly improved in the maintenance unit. For example, the expectations concerning one’s own work had become clearer. Also, some of the old routines were changed and in this sense the organization was “woken up” as they had to form new routines and ways of working and also pay more attention to the costs of the maintenance activities.

Culture-measure at FKA

Figure 8 depicts the results of a measurement made with CULTURE-survey as part of the NKS-project in 2002. The cultural assessment was made almost two years after the reorganization and consisted of twelve interviews and the survey (see Reiman et al. 2004b, 2005a). It did not thus specifically focus on the organizational change, but the results clearly indicated that the change was still affecting the climate at the maintenance unit.

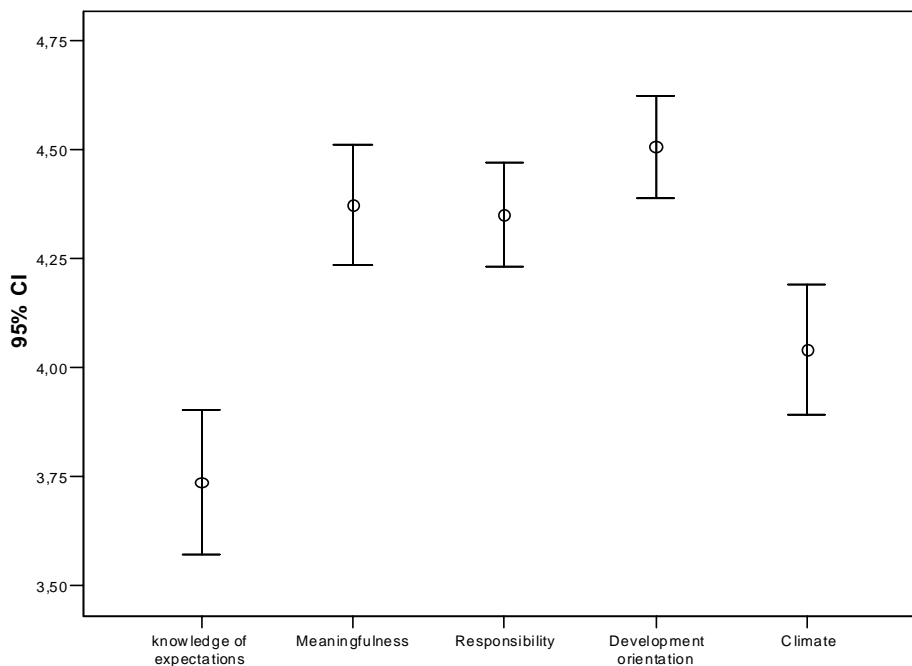


Figure 8. Conceptions concerning one’s own work in the aftermath of the reorganization (from Reiman et al. 2004b). The response scale was from 1 (totally disagree) to 6 (totally agree).

At the interviews conducted in 2002 (Reiman et al. 2004b, 2005a), the following categories emerged when the personnel were asked about the demanding features of their work:

- **prioritising the tasks, the work load** (6 persons)
- **seeing the goals, trust in the management** ("the purpose of the reorganization") (4 persons)

- **social demands** (3 persons)

- **technical competence** (2 persons)

The reorganization was brought up spontaneously in numerous instances. From the interviews and the survey results several indications were obtained that one of the problems at the new organization was to allocate resources in a wise way and to know the current work load of the personnel. Especially managers had difficulties in arranging the work tasks, allocating the resources and planning the everyday activities. On the other hand, some of the personnel felt that the new matrix organization did spread the work load more evenly than it had been spread in the previous organization. When asked about the development targets, clarification of the new organizational structure was the single most frequently mentioned item. (Reiman et al. 2005a) Many people also commented on that the actual work (micro processes) had not changed so much in spite of the reorganization but that much energy was devoted to “clarification” of how the macro processes should be implemented in the new organization (Reiman et al. 2004b).

The change had also made it more difficult to structure the communication in the unit. Due to confusion in the organizational structure, the technicians emphasized the meaning of face-to-face communication over formal structure. The current maintenance organization evoked mixed feelings. Many found the matrix form confusing. On the other hand, there were also signs that the new organization had led to a broader scope of work tasks and to positive challenges in one's work. On the downside there were indications that the new maintenance organization had led to negative changes in the perceived ownership for the technology – previously the maintenance organization had been separate for each station. Indications of a general cost pressure that affected the maintenance organization were also found: “it is talk about costs all the time” and “costs have got a too high focus”. Clearly, the change in the structure had affected the individual psychological dimensions of the work (Figure 6) in ways that had not been fully anticipated.

In order to manage the situation, the social aspects of the organization were emphasized by the personnel (e.g. good team spirit). Reiman et al. (2005a, p. 342) speculated about the possible adverse effects of the change: “gathering and interpreting systematic information of the entire plant condition is extremely demanding in the current situation. This may lead to increased events because the knowledge concerning the plant’s state either does not exist or is not shared sufficiently.”

Due to e.g. the above mentioned problems (see also Section 3.3), it was decided to change some aspects of the organization a couple of years after the reorganization. One of the most important changes was to replace the matrix organization with a more traditional line organization.

Some results of one of the evaluations of the organizational change at OKG

In spring 2003, some 2 ½ years after the maintenance change one survey was conducted at OKG that focused on the situation before and after the change. The results presented below are derived from the maintenance department. The respondents were asked to answer how they judged the situation to be after the change compared to the situation before. 30 different questions were asked, and the scale was from 1 to 5 where 1 indicated that the situation definitely was worse than before the change, and 5 that the situation definitely was better than before the change. 3 indicated that the situation was more or less the same. The results of the survey were quite negative. Some specific results were that:

There might be problem areas that relate to the clarity of responsibility which could explain the experienced problems regarding the availability of information and feedback regarding the delivered information.

- Several questions addressed this issue, two questions in particular. The first question addressed the clarity of one's own assignments and the second question addressed the situation in general with regard to responsibilities and authorities. These two questions got an average below 3 points.

There are indications of problems regarding resource management, e.g. tools, time, and personnel

- Several questions addressed this issue, three questions in particular questions. The first of these questions addressed the availability of one's own access to personnel with the correct competence, the second question addressed the availability of time, and the third question addressed the availability of resources in general, for example money, tools etc. These questions also received an average score of below three points.

One of the more positive effects of the organizational change as mentioned in the survey was that it was considered that the working procedures had been somewhat more standardized. The question which dealt with this issue got an average of above 3 points.

The safety culture survey conducted 2004 showed that the results, after being quite negative 2001, 2002, and 2003, are approaching the positive values it had the year 2000. The reasons for this, other than the effects of the "running in period," might have been that some of the problem areas have been addressed. This means, as an example, decreasing the size of some of the groups, in other words increasing the number of managers.

Some positive co-ordination benefits which were mentioned in the interviews conducted during the spring of 2005 were that the organizational change had increased the cooperation and experience feedback between the different units – some of the goals that were set up in the beginning of the change.

Further findings from all the units

Some **unexpected consequences of the changes** were found. In one of the units the number of late failure repairs rose dramatically after the reorganization. This was hypothesized to be due to e.g. unclear responsibilities (no-man’s-areas) and lowered goal clarity and sense of personal responsibility (“not my fault repair”). After a couple of years the responsibilities had become much clearer, and the personnel actually reported that the working climate and organizational goals were clearer than before the change. Work stress had increased a little though. This could be due to the increased cost pressure and the slight decrease in the number of personnel after the organizational change. In Figure 9 there is depicted the hypothesized influence of the organizational change on the individual persons working at the given culture. These changes affected the performance of the personnel, and lead to increase in the late failure repair.

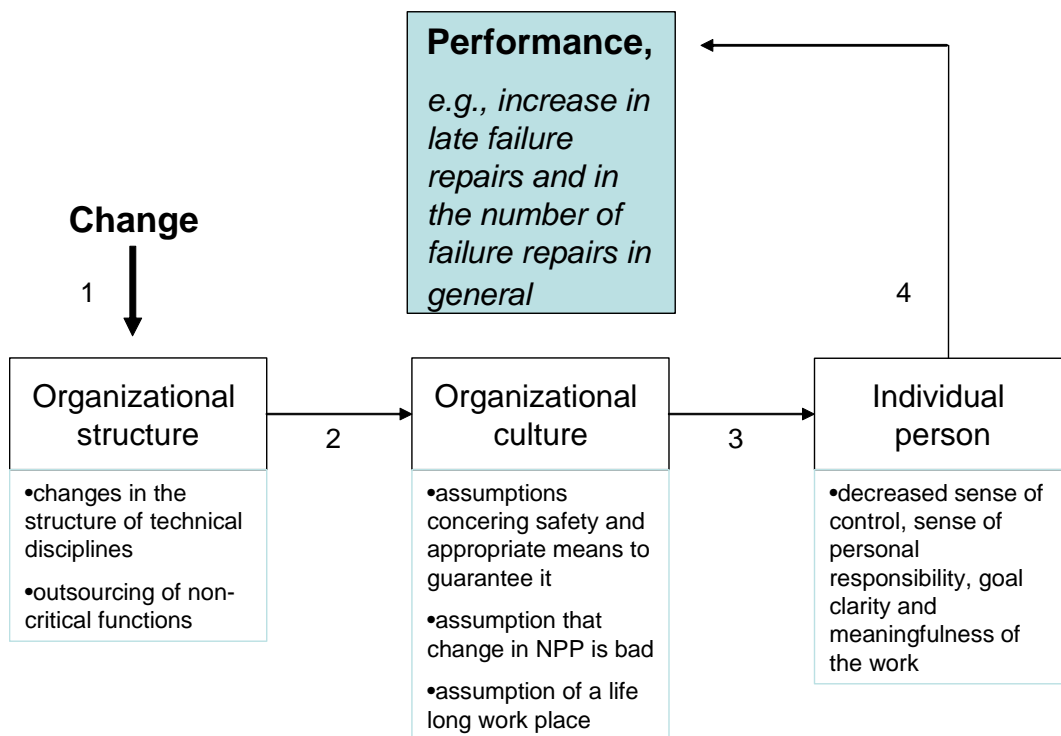


Figure 9. Model of the hypothesized influence of the organizational change on the number of late failure repairs.

Also **incremental changes** affected the performance at all times at the maintenance units. In one maintenance organization, a technician noted that due to the increase in bureaucracy and various control mechanisms, one is not tempted to notify the small equipment defects that one might

spot, since it leads to a massive paper work on the part of the informant. An incremental change in the organizational structure (increase in control mechanisms) had lowered the technician's sense of personal responsibility over one's own work. Thus, he felt no longer personal responsibility over the condition of the plant and acted accordingly.

The way of implementing the change was often criticised at the case plants. One interviewee pointed out:

“In my opinion, the objective of the organizational change was good, but we should have followed another implementation strategy in which we should have put more emphasis on the different individuals. Now we designed the organizational chart without considering the individuals different, “more soft” conditions, for example regarding power of initiative and willingness to take on new challenges.”

At another plant one interviewee commented that he would have wanted to see more leadership and people management skills in the change and afterwards. Another interviewee from the same plant said that the change initiative was planned in too short a time and without consulting the personnel enough.

We found implications that in some of the case plants the growing **economic focus** was considered stressful and as potentially threatening safety. For example, one interviewee noted his worry:

“In my opinion we cannot reduce personnel and other resources anymore now if we are to live up to the high standards of the nuclear industry. Maybe we have already reduced too much.”

In many personnel interviews at the case plants, the growing economic focus was also spontaneously raised as an incremental change that had been going on for some time and was experienced as worrisome and stressful.

On the other hand, we also found implications that organizational changes and economic pressures as such do not seem to affect the safety climate or safety culture as defined by the employees valuing safety (cf. Reiman et al. 2005a). Instead, as shown in this report, the changes affect more the psychological dimensions of work, such as meaningfulness and sense of control. Changes that seem to endanger safety (cf. citation above) are experienced as highly stressful, especially *since* safety remains highly valued. So called resistance to change can thus actually be genuine commitment to safety. Still, incidents can be caused by e.g. unclear organizational structures, degradation in the communication climate at the organization, or low sense of control among the workers (Reiman et al. 2005a). Also, if changes lead to e.g. lowered sense of personal

responsibility as in some of the examples given above, the resulting performance can be such that safety issues are not given so much attention. This is due to the fact that the employee no longer feels personal responsibility over the safety of the plant or over the results of one's own work.

5.4. Drift and incremental organizational change

Structural and cultural issues affect the individual, but the influence goes to the other direction also. Weakened sense of control among a lot of employees can gradually lead to avoidant and self-defensive culture, and this in turn can eventually influence for example procedures that are taken into use, or the choice of tools deemed necessary to carry out the task. Also, as depicted by the arrows in Figure 6, organizational culture is never perfectly static. It is constantly changing and adapting. Structural solutions and tools shape the culture, as do the individual persons with their own values and orientations. In some cases this can lead to e.g. gradual local optimization of working practices (within subcultures at the NPP organization), normalization of deviance or gradual change in the shared principles of decision making in the organization.

These kinds of influences have been depicted by e.g. Vicente (2004), Rasmussen (1997), Vaughan (1996) and Snook (2000). Vicente (2004, p. 276) writes that "accidents in complex technological systems don't usually occur because of an unusual action or an entirely new, one-time threat to safety. Instead, they result from a systematically induced migration in work practices combined with an odd event or coincidence that winds up revealing the degradation in safety that has been steadily increasing all the while". Snook (2000) concludes on the basis of his extensive accident analysis of a shoot down of two friendly helicopters in Iraq airspace that one of the reasons for the accident was what he calls *practical drift* of the practices. He writes: "practical drift is the slow steady uncoupling of practice from written procedure" where "locally practical actions within subgroups gradually drift away from originally established procedures—those conservatively written rules designed to handle the worst-case condition when subunits are tightly coupled" (Ibid, p. 194). These changes are incremental and not usually perceived as changes at all; they are part of the everyday work. This makes them especially difficult to explicitly manage. Nevertheless, after a while these changes influence also the psychological dimensions and the structural issues (Figure 6) in the organization.

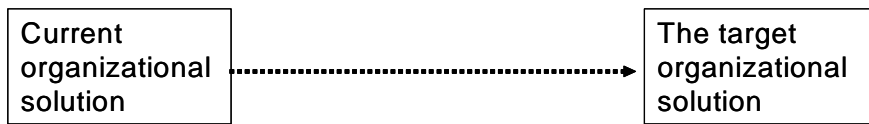
Overall, we have found plenty of indications that the content of the individual jobs is gradually (and incrementally) changing in maintenance work. Especially the role of foremen has shifted from participating in the field work to supervision of work from the computer, planning the work and analyzing data concerning the equipment. This incremental change has evoked mixed

feelings (Reiman et al. 2005a). Some foremen were afraid of losing the touch to the field work and to their workers and the equipment. However, the enriched and more analytically oriented job content has been experienced as challenging by some. It was speculated at some of the maintenance units, however, that the quality of the daily work planning could suffer on the long run because the foremen do not have the same touch to the field anymore. The current focus on strategic optimization and new information technology can threaten the traditional conception of proficiency (based on handicraft skills and practical experience) among the personnel (both technicians and foremen). The new expectations created by the new technology are not congruent with the old cultural conceptions of a skilled worker. The personnel do not want to see the machinery as merely numbers on a computer screen or data base, but as concrete objects to work and play with (cf. Zuboff 1988, Orr 1996). New technologies, the new forms of organizing work (e.g. outsourcing, matrix organizations) and new maintenance strategies (e.g. condition monitoring, predictive maintenance) are thus not only changing the structure, but also the nature of the maintenance work. Thus, they affect how the personnel experience and perceive their work (cf. Figure 6).

6. Conclusions

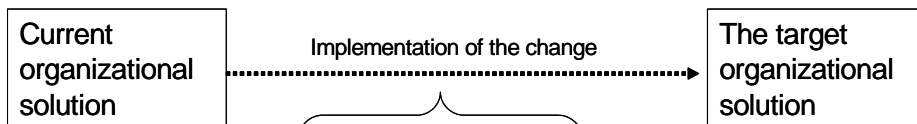
The nuclear industry and especially the maintenance activities have been under various restructuring initiatives in addition to continuous incremental change due to e.g. new technologies, ageing plants, deregulation and the change of generation. These changes have been experienced as causing stress and uncertainty among the workers. Also, changes have led to e.g. lowered sense of control, goal unclarity and lowered sense of personal responsibility over one's work. Personnel's experiences are not merely resistance to change; they are also genuine worry about the safety implications of the changes (Reiman et al. 2005a). The paradox is that if the safety worry of the personnel is not dealt with adequately, it can lead to degradation in the psychological prerequisites of effective work, thus endangering safety. The psychological factors of work should be more carefully taken into account in the change initiatives in the nuclear industry.

The approach taken in the nuclear industry to manage organizational change (e.g. IAEA 2001, NEA 2004) has been derived from the process of managing plant modifications. It is good that organization changes have been noticed to require planning, implementation and reviewing. Further, project-like management of changes is an improvement and gives a chance to evaluate the organizational reliability during and after the change. However, the focus in these change management models is mostly on the structural aspects of the organization and the change management models are quite straightforward in nature. The guidelines of NEA, for example, seem to assume that if the new organizational solution and the implementation programme have been well planned the risks of the change are known and can be controlled. The risks of organizational changes are attributed to the adequacy of the new structure. We acknowledge the risks associated to new structures, but as we have argued it is not the structure per se that should be evaluated and managed during the change. At least three viewpoints should be taken when anticipating the consequences of an organizational change (Figure 10).



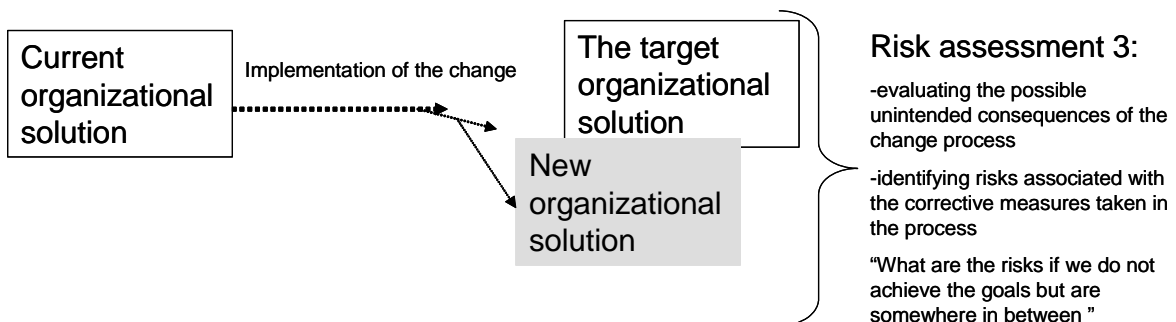
Risk assessment 1:

- Comparison of the current organizational solution of the new one (e.g. gap analysis)
 - identifying risks associated with the goals of the change and the new organizational solution
- “what are the risks if we work in that way in the future”



Risk assessment 2:

- evaluating the change implementation strategy and methods
 - identifying risks associated with the implementation phase
- “What are the risks during the transition if we follow this implementation strategy”
- “Can we reach the goal if we follow this implementation strategy”



Risk assessment 3:

- evaluating the possible unintended consequences of the change process
 - identifying risks associated with the corrective measures taken in the process
- “What are the risks if we do not achieve the goals but are somewhere in between ”

Figure 10. Three viewpoints to anticipating the risks of organizational changes.

The first viewpoint has been endorsed by NEA and IAEA and we acknowledge its importance. However, we argue that in addition to structural issues also the other aspect of the organization (culture and individual person) should be taken into account in the assessment (cf. Figure 6). The second viewpoint has been suggested by the general change management literature and it is in accordance with the results of our case studies. Plenty of problems and risks of the organizational change stem from the implementation phase. The third viewpoint arises from the nature of organizational dynamics. In complex organizations, all consequences of change cannot be anticipated, and usually the end result of the change is not exactly the organization as it was formally designed. The risks associated to these issues are typically not taken into account in traditional models of change management.

Mills (2003, p. 88-97) characterises the typical features of models of organizational change and the rhetoric of change management in general. She argues that the models are typically simplistic, they reference mythical forces (such as “globalization” or “forces of change”), they offer unique solutions to organizational problems, and they are optimistic in tone. Furthermore, they are based on an idea of an all-knowing manager, one who is able to grasp the underlying problematic and take appropriate action, that is, to utilise the given technique successfully.

The features depicted by Mills are usually more or less implicit in the models. They are thus also incorporated in the five elements that Dunphy (1996) suggested as being found in any comprehensive theory of change (see Section 2). These elements should be made explicit, and their relevance for managing change in safety critical organizations should be clarified.

The first element of Dunphy’s list is a metaphor for the organization. Nuclear organizations are not easy to position in conventional organizational taxonomies. During outage periods, for example, considerable planning must be made in order to find an efficient and safe temporary outage organization that can handle many parallel activities during a relatively short time period. Handling of disturbances and accidents demand special organizational arrangements, and modernisation projects such as introduction of new technology also present many challenges for the organization with respect to organizational skill. When one talks about basic metaphors about organizations it is therefore important to realize that NPPs are socio-technical systems which must satisfy requirements in different operating modes. For example, one type of reorganization may present many benefits for a normal operating mode while it could have drawbacks for handling of disturbances etc. Rather than picture organizations in terms of organisms, machine bureaucracies or some other metaphor for an organization (cf. Morgan 1986), we prefer to highlight the basic tree dimensions of structure, culture and individual. Although this

conceptualisation is far from new and original we think it is sufficient in many cases to provide an analytical base structure for understanding important aspects of change management. We propose that organizational change always should be perceived from at least those three perspectives.

Another issue raised by Dunphy is the need for an ideal model of an effectively functioning organization. One may think of ideal organisations in many different ways. An easy way out is to suggest that organisations must be adaptive. But the more precise meaning of such a suggestion is more difficult to elaborate on. For example, there seems to be more or less chronic difficulties in nuclear power organization (and similar complex organizations) with respect to handle the trade-off between stability/robustness and flexibility (which among other things have led to the research tradition focusing on high reliability organizations, HROs). This problem of simultaneously satisfying requirements for stability and at the same time exhibit the dynamic feature of high adaptation may turn out to be one of the more difficult issues for safety science and practice in the future. In the model suggested in this report, we may think about the above problem in the dimensions of structure, culture and individual characteristics. For example, with respect to the cultural dimension, a stable culture usually has the benefit (even if it is not very functional for some given purpose) that people learn both in and outside the given culture the “rules” of the game; that is, what to expect in various situations.

Reiman and Oedewald (2002, submitted) have used the term organizational core task to denote the motive of the activity of the organization and the requirements and constraints that it has to fulfil. Organizational effectiveness and safety are achieved when the cultural way of responding to the core task demands is adequate and based on an accurate conception of the OCT. In organizational changes, care must be taken that the organization does not lose its ability and willingness to fulfil the requirements of its core task.

Change management literature deals usually with changes that are initiated by the top managers. It is important to acknowledge that middle managers, line supervisors and also the shop-floor workers have an influence on and present a potential yet underused source of change initiatives (cf. Griffin et al. 2004; Spreitzer & Quinn 1996). Especially the subordinates of the managers usually have critical information about the functioning of the organization (both its structure and culture) that is critical to the success of the change initiative. Further, changes are usually heavily technology driven (cf. Clegg & Walsh 2004). Human factors are considered only when problems occur, e.g. the personnel show “change resistance” or do not otherwise act as planned by the

change agents. We have advocated a view where the three dimensions of organization are considered together from the start.

One change model is illustrated by the system group model (Andersson and Rollenhagen, 2003) – this model that stresses that the change process should be perceived in a system perspective. The simple idea is to create a so-called system group which contains representative from the whole system so that various changes can be simulated in the group by receiving feed-back from all the important actors. For instance, if a change is planned in a maintenance department, the system group technique would stress that many different stake holder also outside maintenance should be involved in the change process and the design of the changes. Another good effect of system groups is that the people involved in the change process usually take more responsibility for the change process, simply because they were involved in the design of the change.

Technical modifications at nuclear power plants are normally associated with detailed rules and quality prescriptions aimed to support the change processes. This is, of course, a highly reasonable strategy since weaknesses in technology may be a direct threat to reactor safety. Technology does not arise in a vacuum, however – it is embedded in an organizational, social and cultural setting which influences how technology develops and how it is managed. Changes in technology may imply changes in organizational structures, something that indeed should be considered in “technological” change management (and an issue that we feel should receive more attention). In this paper, however, we did focus on more direct structural changes in nuclear organizations. To defend an enhanced attention upon such structural changes one may consider both rational and empirical arguments. For example, if it is accepted that such things as good communication and clear definition of responsibilities makes a difference for safety one should of course also accept that those organizational changes that might influence these factors are important. Moreover, a host of examples focusing on in-depth investigations of accidents and disasters clearly confirm that organizational changes very likely have contributed to these events.

Understanding and managing organizational change management is partly an issue of language and conceptualization. Whereas nuclear organizations generally have developed a rich language to reason about technology, a corresponding rich and nuanced formal written vocabulary supporting organizational change was not seen in our case studies. This is of course not surprising in view of that NPPs are engineering organizations with the particular characteristics associated with such cultures. On a more global level, however, the same rationalistic and programmatic engineering strategies (and associated language) that are used for technological

change management were in our cases often assumed to hold also for organizational change management.

NEA's (2004) suggestion describing a set of steps to follow for managing organizational change in NPP's offers limited practical help for the change manager and seems to underestimate both the dynamics and the cultural aspects of organizational change. On the other hand one could argue that a soft start for introducing a developed conceptualisation for organizational change management should be wise: a first step then would be to increase the attention on the subject and provide a simplified model of the dynamics of organizational change. The Figure 6 aims to do that.

In Sweden (and also some other European countries such as the UK) regulatory demands on the operators with respect to organizational change management in NPPs have been introduced but confusion still exists regarding, for example; about the definition of change and how a risk analysis of organizational change should be designed. There might also be unclarities regarding what information should be included in the risk analysis versus the safety evaluations. One may expect that a period of trial and error concerning formal risk evaluation strategies of organizational change will take place in the nuclear industry. It is highly unlikely, as we perceive it, that methods of supporting organizational change and the risk evaluation of such changes should take the shape of a set of algorithms in terms of "steps" to consider. The studies conducted as a basis for this report rather support a strategy based on increased awareness about cultural factors in organizations. Managers who fully realize that nuclear power plants consist of a host of different subcultures with corresponding differences in values and orientations, will presumably also use change and evaluation strategies that are sensitive to these cultural differences. Instead of suggesting more or less self-evident "steps" for supporting change management we suggest a general strategy based on *heuristics* of change management. Like in the noble game of chess, heuristics for playing only tells you what might be valuable but do not provide definite and deterministic solutions for the problems of change management:

- Prepare for the reorganization by teaching the organization a *rich language* for these matters. If the members of an organization learn to analyse and talk about organizational changes in a nuanced matter, it is presumably easier to see both good and bad aspects of various suggestions. This means for example talking in terms of the dimensions identified in Figure 6.
- Do not nurture an oversimplified image of an organization. Acknowledge that organizations are complex and dynamic social structures the understanding of which

requires rich language and concepts, not only sequential change models and organizational charts. Acknowledge that organizations are more than the formal structure implies; they have plenty of informal features which influence the daily work.

- Realize the multidimensional properties of how people evaluate messages. What is said in terms of truth or not (fact) is one thing. Messages are however also evaluated in terms of what is not said (hidden agendas). Organizations are political entities – that should not be forgotten. Individuals and groups are not keen on changing those things that decrease their chances of influencing and knowing about the things that are happening in the organization.
- Try to anticipate the effect of structural changes on culture and individual workers. This may also indicate new risks of the change not taken into account in structural terms (e.g. change that threatens the prevalent cultural norms is resisted more and is also experienced as more stressful if forced into the organization)
- Take culture and subculture in consideration. What appears as a reasonable solution for one group might have negative effects for another group. Especially when communication patterns or power relations are in “danger” of changing, subcultures exhibit a strong influence on the change process. Further, subcultures have different ways of working and combining groups without paying attention to their cultural differences may manifest as problems of communication and cooperation within the new group.
- Be sensitive to how the communication structure might be changed. In several of the case studies explored above, difficulties in communication during and after the reorganization were found.
- Pay attention to the following experiences of the personnel: how is the sense of control over their work changing, are they feeling they are doing meaningful work in the new structure, do they know what is expected of them, and do they retain a sense of personal responsibility over their work even in change situation when things are not always under their control.
- Expect personnel to express worry about the safety consequences of changes and communicate these issues with the personnel. Do not hide the inherent uncertainty that every organizational change has about its effects. Take the safety worry of the personnel seriously. If they worry about safety too much due to the organizational changes, the ensuing stress might affect safety negatively!
- Do not treat stress and deteriorating climate as “normal” consequences of organizational changes. These issues might have adverse effects on both safety and productivity, but

they can be taken into account by treating organizational changes as an interplay between structure, culture and the individual workers.

- Take into account the delayed feedback of the effects of the organizational change. For example in maintenance the effects of bad maintenance may manifest after a long time. This same applies to successful change initiatives; they usually show on the indicators only after a while.
- Do not forget corrective measures. The best thing we know about organizational changes is that we usually do not end up precisely where we aimed at and that the process is iterative in nature requiring many corrective measures along the way.
- Finally, pay attention to the good side effects of both failed and successful reorganizations: latent errors might be discovered when personnel and practices change and old routines are broken, personnel might “wake up” and be more attentive, learning opportunities rise whether wanted or not. The process of changing things is sometimes beneficial itself and teaches a lot about the real functioning of the organization.

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Appendix A. Organizational change and safety – literature review

Research in non-nuclear domains

Technological changes have profound influences on the social aspects of work (e.g. power relations, interaction, sharing of knowledge), as shown by e.g. Barley (1986, 1996) and Zuboff (1988). Also organizational changes, such as mergers and acquisitions (Stensaker et al. 2002), outsourcing (Clarke 2003) and privatization (Cunha & Cooper 2002) have been shown to negatively affect the organizational climate, employee wellbeing and ultimately also organizational performance. Changes in the organizing of work and in the work itself and various organizational changes and the associated uncertainties among the personnel have been found to cause work stress in various work domains (Ashford 1988, Fairbrother & Warn 2003; Bordia et al. 2004, Kinman & Jones 2005, p. 110).

The survey conducted by HSE in 1996 did not identify “any formal research which explicitly examined the wider effects of reorganisation on health and safety, such as the impact on major hazard safety” (HSE 1996a, Wright 1998). They did identify some examples where reorganization has contributed to major accident, including the 1989 explosion at a petrochemical plant in Texas with 23 fatalities, which occurred in the context of contractisation. On the other hand, “industry level statistics for employees in those sectors experiencing great change, including the rail, power, water and petrochemical sectors, do not consistently reveal a decline in performance, with most sectors revealing improvements in reported accident and injury rates” (Wright 1998, p. 208). They conclude that “reorganisation can be a stressful process and that health and safety standards can be effected in both positive and negative ways” and that the negative effects of reorganization on health and safety “are due to, or at least exacerbated by, deficiencies in the approach taken to the planning and implementation of changes” (Wright 1998, p. 209).

Wright (1998) also reports the findings from 10 case studies made by HSE (1996b) in organizations that had undergone or were currently undergoing significant organizational change. The organizations were selected from sectors where safety and health hazards are considered to be significant. The organizations were:

- power generator
- railway operator
- NHS Trust hospital
- aircraft maintainer

- quarry firm
- water utilities company
- chemicals manufacturer
- drinks manufacturer
- nuclear company
- postal collection and distribution company.

In the cases where the enhancement of safety was set as an explicit objective, various positive outcomes were identified, such as reduction in accident frequencies. The reorganization was viewed more as an opportunity than as a threat to health and safety by the managers. The potential of the reorganization to affect health and safety in a negative way was acknowledged though. Wright concludes by stating what the survey **did not** find:

- formal assessment of the safety implications of reduced staffing levels
- the application of quantified risk assessment to the assessment of forthcoming organization and managerial changes on health and safety
- benchmarking
- assessment and/or monitoring of the impact of major organizational changes on health, particularly mental health, absenteeism and sickness levels. Similarly, only few organizations assessed attitudes or tried to use attitude measurement in assessing the impact of major organizational change on safety related attitudes and beliefs
- with the exception of the nuclear organization, companies focused on the assessment and planning of proposed changes rather than the management of the process of change. Accordingly, the level of information on how to manage the process of change is limited (Wright 1998, p. 214)

Valtee (2002) has studied organizational changes of various magnitudes in seven Finnish hospitals. He found that 90 percent of the employees' feelings toward the change were "change as a threat", and only 10 as "change as a positive challenge". The main sources of negative perceptions were (A) suspicion concerning the reasons and explanations for the change initiative (B) worry and sadness over the disruption of a well working community (C) worry about maintaining the quality of the work (D) worry about one's own work, its continuity, content, working conditions and workload (E) a concern that conflicts, tension and cliques increase.

Ramanujam (2003, p. 614) argues that "current explanations of the organizational origins of accidents understate, or even ignore, the role of organizational change." He shows empirically how discontinuous organizational change in a financial institution increased latent errors

(deviations from procedures and policies), especially in “high-risk” units such as foreign exchange trading (in contrast to e.g. savings accounts operations). On the other hand, he found that in the units where there had been no changes the base rate of latent errors were higher in the low risk than in the high risk units. The latent errors were identified in internal audits. Vicente (2004, p. 250-269) illustrated how downsizing in the Ministry of Environment in Ontario, Canada contributed to an accident where poisonous substance was let into a water system at the town of Walkerton².

Baram (1998) provides evidence of accidents at the chemical and petroleum industries which have been caused in part by downsizing and outsourcing activities by the corresponding companies. He proposes that before organizational change that involves downsizing is undertaken the company should evaluate its implications for e.g. the safety management system, “with particular attention given to increased stress and other ‘human factors’ on the retained workforce and the efficacy of using temporary workers to implement necessary procedures and participate in the company’s organisational learning system” (Baram 1998, p. 203). He further recommends that the safety implications of the change should be evaluated with special attention paid to the transition period, and that the company should ensure that its contractual arrangements do not derogate company responsibility for workers and public safety.

Bier et al. (2001) studied the effect of deregulation on safety in U.S. aviation and rail industries and the United Kingdom nuclear power industry. They raised the issue of cutting corners on maintenance as troubling trend in the industries from the safety point of view. Another issue that had been increased after deregulation was mergers and acquisitions. Their specific findings concerning the nuclear industry will be presented in the next section.

Research and evidence from the nuclear industry

Bier et al. (2001) studied the effects of privatization and restructuring of the United Kingdom electricity supply industry to nuclear safety. They argue that their literature review “produced relatively little meaningful information about the safety impact associated with the British privatization and restructuring”. They discuss three significant audits made by the NII since the privatization. The safety audit at Dounreay is described in detail next.

There were three main factors behind the NII audit at Dounreay in 1997. First, the government of United Kingdom had in 1988 decided to abandon near term research and development of fast reactor technology and close the Dounreay prototype reactor. The decision led to massive

² There were other contributing factors by other agents, but they were not due to organizational changes, and thus

downsizing of UKAEA (United Kingdom Atomic Energy Authority) during 1988 to 1993, who was the owner of the plant site licence. During this period the personnel at UKAEA was reduced from 13 600 to 8300. NII's second concern was reorganization in 1994 where UKAEA was divided into three separate groups. The objective of the reorganization was to prepare for the eventual privatization of two of these groups. The third concern of NII was the way in which the plant site manager utilized contractors (so called managing agency contractor principle).

The audit produced a number of observations, e.g. the following:

1. The corporate reorganization blurred the responsibilities and accountability for safety.
2. Signs of low morale among employees was found, presumably as a result of the recent large-scale changes in the organization and the uncertainty about future employment prospects
3. The NII identified significant shortcomings in both the licensee's and contractors' understanding of the nuclear regulatory system and licensing requirements

They concluded that "the licensee had failed to maintain itself as an "intelligent customer" for nuclear services, and that in doing so, it had effectively relinquished its control of safety management to its contractors. (Bier et al. 2001, p. 7–23).

Bier et al. (2001, p. 7–35) conclude that "the British experience suggest that the impacts of restructuring and downsizing cannot always be accurately predicted by licensees, and that reorganizations can impose burdens on the licensees in excess of their anticipations." As a result of these experiences, a new license condition (#36) has been added to the licence of every nuclear power station in the U.K. The purpose of this Condition is to ensure that the licensee has adequate arrangements to control any change to its organizational structure or resources which could affect safety.

On April 2003, a fuel cleaning incident occurred during a scheduled maintenance shutdown of one of the four units at Paks NPP in Hungary. The fuel assemblies damaged and radiation was let into the environment. Thirty fuel assemblies had been removed from the reactor and placed in a fuel cleaning tank approximately ten meters under water in a shaft adjacent to the fuel pool. The ex-core cleaning system was designed and installed a couple of months before the outage. This system was "unique and unproven", but the complexity of this modification was not understood at the time. The damage to the fuel assemblies was caused by the overheating of the assemblies due to insufficient cooling, followed by a thermal shock by the inrush of cold water into the tank

beyond the scope of this paper, for details see Vicente (2004, p. 250-269).

after opening the tank lid. The water at the shaft was contaminated with a large amount of radioactive isotopes, a part of which was discharged into the air space of the reactor hall by bubbling through water, and into the environment via the ventilation system and the ventilation stack. The collective dose received during the incident prevention and recovery work between 10 April and 10 May was 166.8 person-mSv. (OECD 2005, IAEA 2003b) The cleaning of fuel assemblies had been contracted out in 2000, but the scope of the work in 2003 was more extensive. As a summary of the review by IAEA (2003b) it was noted that the responsibility for operation of the fuel cleaning system had been turned over to the contractor, and as a consequence the fuel cleaning procedures were not developed, reviewed or approved by reactor operations personnel. IAEA (2003b) also noted communication problems between the organizational units, timetable pressures, and uncertainty over the safety significance of the work being done. The contractor worked without proper supervision of the Paks NPP. “The personnel involved did not receive adequate training in the nuclear safety aspects of this specific operation. Additionally, operating and emergency procedures were not adequately developed nor was the plant operations department sufficiently engaged in the supervision of the operation.” (IAEA 2003b, p. 6)

Kecklund (2004) has made a survey of the changes in the Swedish NPPs over the last five years due to deregulation which have affected the maintenance activities. Her objective was to describe the changes and the motive forces behind them and identify those conditions that could influence reactor safety. She identified plenty of changes in people (e.g., the staffing has been reduced and work demands have increased), material (e.g., optimizing of storage space), coordination (matrix organizations, lean organizations), tools (e.g., new computer-based maintenance systems) and information. Kecklund (2004) lists risks that have been identified in the study by the employees:

- too scarce staffing and high work load
- problems with job satisfaction and motivation
- uncertainties as to responsibility and roles in the new organisation
- overloaded coordination capacities
- deficiencies in maintenance instructions when the staff are transferred
- constant focus on cost reductions

She also discusses the way in which the above mentioned issues might influence reactor safety. She writes: “Such conditions are an increased pressure on the staff, high work load and too much overtime, uncertainties as to responsibility and roles, lack of job satisfaction and motivation and deficient maintenance instructions. Each one of these, separately and especially in different

combinations, has a potential to influence safety and quality negatively. Economic pressure and a high rate of change might also give negative influence” (Kecklund 2004, p. 18).

In NEA report of a workshop on regulatory issues related to management of changes (OECD/NEA 2002, p. 13) it is stated that “Human Resources (HR) issues relating to morale, attitudes, motivation etc. were considered to be central to the process of organizational change, but it was difficult to establish their precise safety impact”. Human resource management and organizational climate and culture were also issues that were deemed as most important challenges in the context of safety management by NPP managers in five European countries (Kettunen et al. 2006).

Major organizational changes, especially one’s requiring reductions in the number of plant personnel or other cost reductions (e.g. shortening the time spent for refueling outages) have received increasing attention in the nuclear industry (IAEA 2001, 2003; Bier et al. 2001). Less attention has been devoted to smaller, more incremental changes in organizational structures, tools and practices. These are also organizational changes and being usually non-specific in duration, less immediate in outcomes and less analyzed in possible consequences and interrelations, they are a potential source of gradual drift in practices and culture toward an unsafe condition.

Summary of existing research

In conclusion, organizational changes clearly are issues that have potential effects on safety. Both positive and negative cases on safety effects of organizational changes exist, and various accidents have been pinpointed to organizational changes in the company. The effects of reorganizations are difficult to evaluate. For example, leaving the organization as it is could in some cases be more risky than changing it. The evidence from accidents caused by organizational changes cannot be taken as a proof about the inherent risks of change. The accidents that have been avoided by changing the organization are not so evident as the one’s that have taken place. Thus the overall effect of change on safety is ambiguous. Further, the mechanisms of how safety can be affected for better or worse by organizational changes have remained unclarified. Some common issues of concerns in organizational changes are the loss of competence, deteriorating morale and employee motivation, stress and workload, and vague responsibilities. Most of the research has also concentrated on changes that have involved downsizing or outsourcing. The safety consequences of changes in organizational structure or in the organizing of work have received less attention.

Title	Management of change in the nuclear industry – Evidence from maintenance reorganizations
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Abstract	<p>The nuclear industry and especially the maintenance activities have been under various restructuring initiatives in addition to continuous incremental change due to e.g. new technologies, ageing plants, deregulation and the change of generation. These changes have been experienced as causing stress and uncertainty among the workers. Also, changes have lead to e.g. lowered sense of control, goal unclarity and lowered sense of personal responsibility over one's work. Organizational changes clearly are issues that have potential effects on safety. Both positive and negative cases on safety effects of organizational changes exist, and various accidents have been pinpointed to organizational changes in the company. In this report the challenges of management of change at nuclear power plants are considered mainly from organizational culture -perspective. The cultural perspective taken in this paper strives to combine technical approaches to human resources approaches. The report focuses on evidence gathered from studies made at Nordic NPP maintenance units, but the results and models depicted in the report are of general relevance in the nuclear industry. The report is based on four case studies of reorganizing in NPP maintenance units and on a literature review of change management at various other safety critical organizations. The report presents a framework for considering organizational changes and their safety consequences.</p>
Key words	nuclear power, organizational change, safety culture, maintenance, human factors, change management