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Research

Safety Management Characteristics Reflected in Interviews at Swedish Nuclear Power Plants:

A System Perspective Approach

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SKI

SKI PERSPECTIVE

Background

SKI has had a three-year research project on safety management running. In earlier studies the authors introduced a system perspective on safety management. The overall purpose of the on-going study has been to find a general framework for modelling safety management by establishing a frame of reference and analyzing safety management from a non-nuclear point of view with potential relevance for nuclear safety.

Purpose

This report is the result of a study with the aim of investigating safety management in the nuclear power industry, and to use the system theoretical framework from earlier studies in the analysis of the results.

Results

The study used the themes identified in an earlier study: definitions of safety management, the structure of the organizations, organizational change, regulatory and operational activities, safety strategy, threats to safety, information management and feedback, incident and accident reporting, and measurement of safety. The results give interesting insights and important reminders on different aspects of safety management in the nuclear context.

Continued work

The next study will also involve the nuclear context, focusing on a study of licensee event reports.

Effects on the SKI regulative work

The results give emphasis to the importance of the field. The frame of reference for safety management described in the report is one that can, when fully developed, have the potential to be a support for SKI when choosing strategies to enhance the regulatory work on safety management.

Project information

SKI project coordinator: Lars Axelsson
Project number: 14.3-030300

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A System Perspective Approach

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Summary

The present study investigated safety management characteristics reflected in interviews with participants from two Swedish nuclear power plants. A document analysis regarding the plants' organization, safety policies, and safety culture work was carried out as well. The participants (n=9) were all nuclear power professionals, and the majority managers at different levels with at least 10 years of nuclear power experience. The interview comprised themes relevant for organizational safety and safety management, such as: *organizational structures and organizational change*, *threats to safety*, *information feedback and knowledge transfer*, *safety analysis*, *safety policy*, and *accident and incident analysis and reporting*. The results were in part modeled to important themes derived from a *general system theoretical framework* suggested by Svenson and developed by Svenson and Salo in relation to studies of "non-nuclear" safety organizations (e.g., Svenson and Salo, 2004). A primer to important features of the system theoretical framework is presented in the introductory chapter. The results from the interviews generated interesting descriptions about nuclear safety management in relation to the above themes. Regarding organizational restructuring, mainly centralizations of resources, several examples of reasons for the restructuring and related benefits for this centralization of resources were identified. A number of important reminders that ought to be considered in relation to reorganization were also identified. Regarding threats to the own organization a number of such was interpreted from the interviews. Among them are risks related to generation and competence change-over and risks related to outsourcing of activities. A thorough picture of information management and practical implications related to this was revealed in the interviews. Related to information feedback is the issue of organizational safety indicators and safety indicators in general. The interview answers indicated that the area ought to be explored further. Future research in the areas of: (a) outsourcing; (b) system theoretical integration of MTO features at a unitary level of abstraction, exemplified in relation to the development of organizational safety indicators; and (c) new approaches to organizational optimization in contrast to traditional restructuring, were suggested and discussed.

Sammanfattning [Summary in Swedish]

Föreliggande rapport utforskar säkerhetshantering (inkl. säkerhets ledning) karakteristika speglade i intervjuer med deltagare från två svenska kärnkraftverk. En dokumentanalys avseende verkens organisationer, säkerhetspolicies och säkerhetskulturarbete, utfördes också. Deltagarna (n=9) var samtliga erfaret yrkesfolk och majoriteten arbetade i olika chefsbefattningar med över 10 års erfarenhet från kärnkraftssektorn. Intervjun omfattade olika teman relevanta för organisationssäkerhet och säkerhetshantering, så som: *organisationsstrukturer och organisationsförändring*, *hot mot säkerheten*, *informationsåterkoppling och kunskapsöverföring*, *säkerhetsanalys, säkerhetspolicy*, *samt olycks- och incident analys och rapportering*. Resultaten belystes delvis i relation till viktiga teman ur det system teoretiska referensramen som föreslagits av Svenson och som utvecklats av bl.a. Svenson och Salo i samband med studier av "icke-nukleära" säkerhets organisationer (e.g., Svenson and Salo, 2004). En introduktion till viktiga egenskaper i den systemteoretiska ramen presenteras i introduktionskapitlet. Resultaten från intervjuerna genererade intressanta beskrivningar om säkerhetshantering i kärnkraftverk i relation till ovanstående teman. När det gäller

omstrukturering av organisationer, framförallt centralisering av resurser, framkom ett antal exempel på orsaker till omstruktureringarna och vinsterna med dem. Ett antal viktiga teman att tänka på vid omorganisationer identifierades också. I relation till risker för den egna organisationen kunde ett antal sådana uttolkas ur intervjuerna. Bland dem, risker relaterade till generations- och kompetensväxling samt risker relaterade till utlokalisering av aktiviteter till externa entreprenörer, sk. ”outsourcing”. En grundlig bild av informationshantering och praktiska implikationer relaterade till det framkom i intervjuerna. Relaterat till informationsåterkoppling är området för organisatoriska säkerhetsindikatorer och säkerhetsindikatorer i allmänhet. Intervjusvaren pekade på att området bör utforskas vidare. Framtida forskning i områdena: (a) ”outsourcing”; (b) systemteoretisk integrering av MTO karakteristika på en gemensam abstraktionsnivå, exemplifierat i samband med utveckling av organisatoriska säkerhetsindikatorer; och (c) nya närmanden till organisatorisk optimering i kontrast till traditionell omstrukturering, föreslogs och diskuterades.

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1 Introduction

1.1 Theoretical background

The present study investigates organizational safety and safety management characteristics reflected in interviews with Swedish nuclear power plants. Themes derived from a general system theoretical framework developed by Svenson (e.g., Svenson and Salo, 2004; Svenson, Salo, and Allwin, 2005; Svenson, in Svenson et al. 2005, pp1-7) constitute the theoretical backbone to the study.

There is an important assumption about that a common frame of reference, or theory is needed in order to integrate human, organizational, and technological aspects of an industry in order to make inferences about how these aspects are related to each other and to what degree individual aspects contribute to the unity compared to the other aspects. The system approach suggested by Svenson could be such a general frame. Traditionally, technological issues are modeled with technological theories, and organizational issues modeled in organizational theories, often in part psychological or economical in nature. There are several reasons that a unified approach is needed, for example, a common terminology for both technological and human-organizational factors is useful, cause-effect relationships are best modeled within the same system, to mention a few. The general system theoretical framework does not challenge existing theories in the field. Instead, it offers an opportunity for merging technological and organizational aspects into one unified approach to safety.

A common model and a common language have always been important features for systems approaches. The prominent general systems theorist Ludwig von Bertalanffy noted that, the enormous amount of data, the complexity of techniques and of theoretical structures within every field, has led to a breakdown of science as an integrated realm (1973, p. 124). Miller (1978) saw similar complications in his studies of living systems and their characteristics. He emphasized that any system, be it social, technical, living, or non-living, can be modeled as a *supra system* consisting of various subsystems. The subsystems are either living systems consisting of individuals or organizations, or non-living systems consisting of the technological parts of the system Millers concepts are adapted for the system theoretic framework used here. According to traditional systems theories (e.g., Miller, 1978) living systems exist in space. They consist of matter and energy that are organized by information. Both living and non-living systems can be described in terms of *structures* and *processes*. The processes are governed by information and driven by energy. Both structures and processes are needed in order to describe each of them. *Processes* are described by the change in the corresponding structure. Bits of information have moved from A to B. *Structures* needs a process to map on the structure. To exemplify, if we want to understand the structure of attitudes of the people working in a nuclear power plant, we ask them to process the information of a questionnaire and to give us an output on paper that we in turn can process to reach a conclusion about the structure of attitudes Svenson, Salo, and Allwin (2005).

In the following section a primer on the system theoretic framework suggested by Svenson will be given in brief. For the interested reader we recommend a closer look at

some of the preceding reports from the authors (e.g., Svenson and Salo, 2004; Svenson, Salo, and Allwin, 2005; Svenson, in Svenson et al. 2005, pp1-7).
Figure 1 shows a hypothetical supra system, the supra system is hierarchically organized consisting of at least two subsystems on the next lower level. In our hypothetical model we have the living/technological system corresponding to the sum of Swedish nuclear activities at the suprasystem-level. On the subsystem level we have the government, the authorities, and the nuclear power companies, each of them consisting of a living or a technological system or a combination of both a living and a technological system.

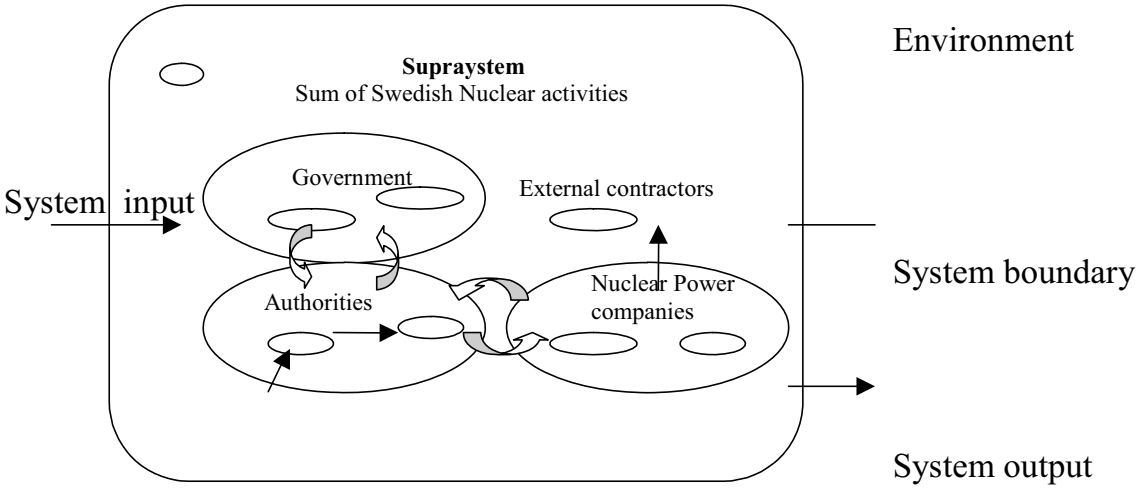


Figure 1: The structure of the hypothetical supra system "Swedish Nuclear activities and its subsystems. Arrows indicate system processes consisting of flows of information, matter and energy.

Translated to organizational concepts, the subsystems may consist of various organizations, which interact to maintain themselves, and the supra system in a steady state. In this hypothetical example this can be safe nuclear operations. Other steady states are also possible. The desired steady state may, for example, be a political agreement of the limits that a system may fluctuate. Such variables can for example be economical output, economical input, or some measure of safety. From this point of view it the conditions needed for keeping the supra system stable that decides the parameter settings for the subsystems. "A system is adjusted to it's supra system only if it has an internal purpose or external goal which is consistent with the norm established by the supra system"(Miller, 1978, p.40).

According to the above definition of a system, system safety is a reference to the stable System State. Safety management from this perspective is a reference to keeping system variables within their limits and thereby keeping the system in a steady state decided by the goals of the sub and/or supra system. If the system variables do not meet the criteria for steady state, the system becomes instable is said to move out of the desired steady state towards another steady state. The system safety is at risk. In order to stop the system from drifting, in technological terms, new parameter settings, reprogramming of the component or replacement of the component may be required. In terms of system

concepts, a process controlling the deviation with negative feedback, driving the system back to its desired steady state is required (Svenson and Salo, 2005).

In the results section, references to the system features in organizational terms are: Organizations – systems/sub systems, Information – system information/ feedback/energy, Threat – risk of system deviation, Safety management – system control. Translation examples between system concepts and organizational equivalents are developed in the preceding reports by the authors exemplified above.

Central concepts from this framework has been applied and evaluated in relation to a number of non-nuclear organizations, The Swedish Civil Aviation Safety Authority, The Norwegian Petroleum Directorate, A Swedish Car Manufacturer, Regulatory and Company organizations of Swedish railway operations, to mention a few (e.g., Svenson, Salo, and Allwin, 2005; Salo and Svenson, 2005; Svenson et al., 2005). The present report brings this intention one step further, and for the first time, attempt to model the concepts from the framework on an interview analysis from Swedish nuclear power plants.

1.2 Aims of the study

The primary aim of the present study is to investigate safety management in nuclear power industry, and to analyze the results in relation to the system theoretical framework developed and tested in preceding studies in non-nuclear contexts (described above). Participants from two Swedish nuclear power plants will be interviewed in this study.

The focus on the following analyses will be on themes that have been identified as important for safety management in relation to the developed systems perspective. The themes are: *the organizational structures and organizational change*, *identified internal and external threats to safety*, *information structures and feedback systems (internal and external communication)*, and *safety policy*. In addition to this, another aim of the study is to offer illustrative examples on good practice regarding safety management within the area of nuclear power production.

The study also intended to analyze documentation promoted from the studied plants as relevant for safety management and organizational safety in general. The documentation was, however, delivered far too late to be included in the present report, and will be reported later in an extended version instead.

2 Method

2.1 Participants

Two Swedish NPP's took part in the study which in all consisted of 9 persons (8 male, 1 female). At the first NPP, from here on NPP1, 6 persons participated in the interviews. The majority of the participants (5) were managers from different operational areas at the plants, all directly or indirectly responsible of various areas of plant safety, and one person was a safety engineer at the plant.
At the other plant, from here on NPP2, three persons participated in the interview, all managers with direct or indirect responsibility of plant safety. A fourth person should have participated at NPP2 but had to cancel short before the interview.
All participants in the study, except one, had 10 years or more experience at the plant or from another plant, and were often promoted through different professions during their time at the company. They were in other words persons with long and solid experience from the nuclear power area. Table 1 lists the participants included in study, and their roles at the plants.

Table 1: Participants in the study, across the two plants, NPP1 and NPP2, and their roles at the plants.

	NPP1	NPP2
	Manag. Safety dept.	Manag. Safety dept.*
	Manag. Maint. Dept.	Manag. Technology dept.
	Manag. Resource (block)	Manag .Prod. (block)
	Assist. Manag. (block)	-
	Eng. Instrument. (Safety ambassador)	-
	Eng. Safety *	-
Σ	6	3

*= contacts at the plants.

2.2 Material

The material consisted of one interview checklist (see Appendix for the full checklist in Swedish). The checklist resembled largely the ones used in preceding interview studies on the theme *safety management in non-nuclear contexts* (e.g., Svenson, Salo and Allwin, 2005; Salo and Svenson, 2005). There are 8 main themes in the checklist (in parentheses below), all with a number of sub items. Number 1 to 3 corresponds roughly to important characteristics of the system theoretic framework suggested by Svenson (ie, Svenson and Salo, 2004; Svenson, Salo and Allwin, 2005), namely, *system structures* and *system processes*, *control*, and *information*. Number 4-8 are questions related to various aspects of safety management. The eight main themes and (1) *The plant's organizational structure, safety, and change processes*, including 7 sub items (recent change processes, affected organizational parts, reasons to change, effects of

change, resource demands, improvements, future improvements); (2) *Threats to safety and how they are managed*, including 5 sub items (internal risks, external risks, changes and threats in "surrounding world", safety indicators, estimation methods); (3*) Information management and systematic feedback*, including 4 sub items concerning internal feedback [internal information transfer, locals, informal information exchange, internal feedback from previous experience (erfarenhetsåterföring) and knowledge transfer systems]; and , 6 sub items concerning external feedback (external information transfer authorities, -//- with other companies, different views on safety, other authorities, departments, external feedback from previous experience and knowledge transfer systems); (4) *Safety analysis and event reporting*, including 10 sub items (stability and development of activities, new risks and risk analysis, internal event reporting sequences, reporters qualifications, report structure, MTO reporting, incidents vs. accidents, internal evaluation of reports, consequences following evaluations); (5) *Safety policy*, including 3 sub items (formal policy, relation policy-practice, important policy aspects); (6) *Regulation*, including 3 sub items (plants description of SKI's regulatory activities, SKI's regulation's relation to internal safety management, improvements concerning regulation own safety work); (7) *Manning*, including 2 sub items (vacancies, needs to increase workforce); (8) The concept of Safety Management, including 3 sub items (explicit definition in organization, internal rooting of concept, external -//-).

2.3 Procedure

First, a letter with information about the study was sent to persons working with MTO coordination at the two plants (one at each plant). They were asked to become our contacts at the plants and to select one group of persons each for the interview. The group of persons should consist of persons that had work experience of issues related to organizational safety and safety management. At NPP1, the MTO coordinator (safety engineer) accepted the invitation, and at NPP2 the task was forwarded from the safety coordinator to the manager of the safety department who also was willing to participate.

The interviews were picked up in mid September (NPP1) and late October (NPP2) 2005, ant took place at the plants. The dates were decided by the plants and were more or less adjusted to times that would impose as little interference as possible with the revisions. The interview answers were recorded by pen and paper by one interviewer (author) according to the interview checklist.

Before the actual interviews, information about the study and the procedures for the interview were presented. The participants were informed that they could stop and ask any questions concerning the interviews and/or study at any time. After this, the participants gave a presentation about their background and their roles at the plant.

One important feature of this study was that we wanted to learn how characteristics of system safety management according to Svenson and co-workers (2004, 2005) could be illustrated in the interviews, and how they reasoned about matters related to the concept of safety management. For this purpose, the interviews started with asking the participants about how they related to safety management in their work. This worked straightforward and the participants had been prepared for this from the contact persons.

After this the interview continued with discussions about the main themes of the checklist. The sub items served only as primers if the participants should run out of ideas, something that never came true. The individual participants had a lot of information to reflect about and to share.

When both interviews were recorded, a clean copy of the interview answers in Swedish each was produced and remitted back to the plants. At this stage the plants had the opportunity to both make comments, and add information. Based on the information added to the interviews, a raw manuscript of the interview data for each plant was produced in English and again remitted to the plants for further comments. At the stage of the first remittance, the plants were also asked to send in supplementary documents for a subsequent document analysis. The decision on which documents the plants should send in was partly based on the results of the interviews. The plants were asked to contribute with documentation resembling:

- An organizational description and chart.
- A safety policy.
- Documentation of work on safety in general and safety culture

In the following chapter, first, the organizations will be described in terms of organizational structures and processes, safety policies, and safety culture work, with reference to the contributed documentation. Second, results from the interviews are presented under a number of headlines resembling the eight main themes of the interview checklist (above). The two plants produced different types of answers to the themes and focused more ore less on different themes. For example, one of the plants had prepared for a presentation of their safety work from an organizational angel. The individual unique ideas were sought after and, there were no attempts to compare the interviews of the two plants with each other. Instead, the results from the interviews must be considered together as ideas concerning safety expressed by experts from the Swedish nuclear power industry.

3 Results

3.1 Documents related to organizational safety and safety management contributed by the NPP's

In the first part of the present chapter, the two organizations of NPP1 and 2 will be outlined. The analysis is based on internal company documents. For this purpose, the NPP's were asked to contribute with documents containing information about the organizational structures, and policies and procedures regarding organizational safety and safety management.

3.1.1 Organizational structures

Organization charts were available from both NPP's. Both organizations were depicted hierarchically (box-tree) with higher order structures and related sub structures easily comprehendible from the charts. It is important to remark that the organizational descriptions relate primarily to the structural hierarchical relationships between substructures, and not necessarily to process relations such as information flow processes or related information carrier structures (information channels). However, these matters are partly revealed in the interviews reported in the subsequent chapter.

Two important differences between the NPP's organizational emphasis was identified in the charts. First, in NPP 1 the production units were depicted as substructures of production among other departments organized below CEO and staff, whereas in NPP 2 they are organized separately directly below CEO, vCEO, and the *safety and environment* unit. Figure 2 shows a simplified lineout regarding how production units are depicted in the charts.

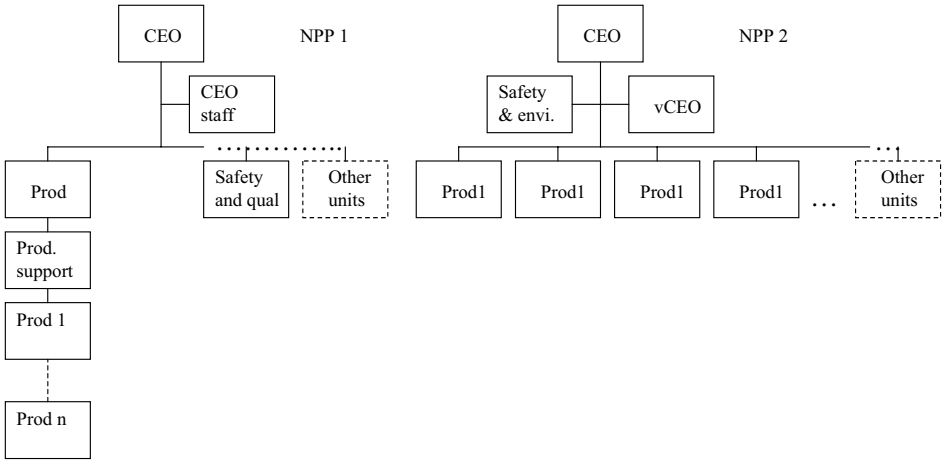


Figure 2: Different emphasis on the organization of production- and safety departments/units between NPP1 and NPP 2. The figure shows only a cut-out of the actual organizational charts with a focus on production and safety departments. The dotted lines indicate that many more substructures are included in the original charts.

Second, relevant to the context of safety management, is the different emphasis on the organization of the safety departments between the two NPP's. In NPP1 1 the *safety and quality* unit is, similar to production, depicted as a substructure among other departments organized below CEO and staff, whereas in NPP 2 the safety and environment unit is, similarly, organized directly below CEO, but at the same level as vCEO.
Irrespective of the reasons behind these differences or their implications for practice, it is important to point out that where one specific unit is placed in an organizational chart may promote different mental models among readers of the charts regarding the organizations.

3.1.2 Organizational responsibilities and control functions

In addition to the organizational chart NPP2 also contributed with an *organizational description* (organisationsbeskrivning), a document which gives a comprehensive view on how the company group has chosen to organize their activities and to distribute the responsibilities in order to create an integrated control of four important parameters: (1) safety, (2) environment, (3) competence, and (4) value-creation (värdeskapande). The document gives valuable information, for example, about a number of important control processes of the company/plant supra system. The document gives a meaning regarding important aspects of system dynamics to the static structural representation of the organization depicted in the organizational chart. Examples of important themes for organizational safety and safety management stated in the organizational description document are given below.

Organizational change
The document points out that following organizational change which may affect the conditions stated in the safety report or which is of principal importance for the management or control of production, maintenance, handling of nuclear matter, work related to safety and quality assurance, and the accident readiness (haveriberedskap), these shall undergo primary and independent safety inspection (primär och fristående säkerhetsgranskning).

Organizational purpose
Two important dimensions of the organizational purpose is to safeguard the economic potential of the company and to crate an integrated control of the four parameters (1-4) above.

Responsibilities and powers
General responsibilities are identified for each part of the organization. For example, the blocks have been assigned the complete responsibility to utilize, run, administer and develop the production plants. Other departments have specific task responsibilities. The staffs for safety and environment are regarded independent from the organization with the task of following up that authorities' and other interested parties' demands on safety, environment, and radiation protection are satisfied. The delegations of responsibilities to named managers at each unit at the plant are stated in the document.

Management control
Management control-functions, -systems,-forms, and different -fora are identified in the document. The safety and environment staffs, and the vCEO staff are controlled directly

by CEO. The safety and environment staffs are controlled toward a number of clearly formulated and measurable quality- and operative goals (verksamhetsmål). The blocks are controlled by the ones responsible for each production plant respectively, on results regarding the four parameters (1-4) described above. The production units and a number of other units are controlled towards a number of clearly formulated quality- and business goals which are possible to follow up. Activities directed towards production units are controlled by cost-, quality-, and performance goals. Units included in technical service are controlled by CEO regarding the general activities and resources, and by the production units regarding tasks. All units formulate their own goals according to the company-group's general goals concerning the four parameters. CEO has distributed responsibilities to unit- and staff managers, and to specific functions, all stated in specific documents referred to in the organizational description document.

Line-organization
The line-organization is described in the document. It is stated that designated co-workers shall, with focus on the four parameters, lead the work of establishing, maintaining, and developing efficient stable processes. The designated process manager is stated in the document.

Infrastructure
Changes in the surrounding world and transfer of experiences both within and outside the organization must be taken into consideration, and continuously be object of continuous evaluations in order to create an appropriate organization.

The different areas outlined above are described in brief in the document, with reference to specific extended documents for each area.

3.1.3 Safety policies

3.1.3.1 NPP1 - Policy documents

NPP1's policy is stated in a separate document named "Policy". It consists of three general paragraphs: (1) We strive after a good safety culture; (2) We have a clear strategy; and (3) We are continuously working with safety. Each of the paragraphs is divided in subsections specifying different sub-areas of each of the three paragraphs. Each sub-area is accompanied with an explanatory text, for example:

Paragraph level:	Sub-area:	Explanatory text:
1. We strive after a good safety culture	a. We always put safety first in order to protect the plant and environment against harm.	To put safety first is a guiding star for the operations. If there is emerging conflict between different goals or interests, safety shall always be prioritized. This holds for all occasions without exception.

Important themes of the three paragraphs are summarized below:

We strive after a good safety culture

- "Safety first".
- Continuous questioning of safety.
- Full safety responsibility for each and everyone.
- Follow safety instructions and routines.
- Openness for society and authorities.
- Information: external and internal.

We have a clear strategy

- Strive towards continuous enhancement of awareness about safety demands.
- Immediate handling of incidents related to deficiencies in depth-defense.
- Continuous systematic safety analyses.
- Look after those sufficient resources are allocated for prioritized measures.
- Safeguard competence support in all segments with safety responsibility.
- Keep an active dialogue with authorities in order to develop and improve safety demands.

We are continuously working with safety

- Follow-ups and evaluations of experiences from the safety policy, and proposing safety improving changes.
- Active processing of own and others experiences of nuclear operations and transfer to interested parties.
- Elucidation and communication of responsibilities and authority.
- Plan and carry out measures in the plants to keep up satisfactory safety limits throughout the lifetime of the plants.
- Activity in research and development regarding safety.
- Work on safeguarding access to suppliers with high safety competence.

The information in the policy document is also distributed in condensed form in a leaflet named Safety *policy Nuclear power (company name)*. The text in the leaflet is almost identical to that in the original policy document, except that the explanatory text is omitted.

3.1.3.2 NPP2 - Policy documents

NPP2 contributed with two documents. The first document resembles a general safety policy document, and is named *General goals and attitudes toward reactor safety* (Övergripande mål och förhållningssätt för reaktorsäkerhet). The second document, named *CEO – directives – reactor safety* (VD-direktiv - Reaktorsäkerhet) consists of interpretations of terms and demands in the *reactor safety area directives* (FOD-fackområdesdirektiv reaktorsäkerhet), and in some cases company-group-, and CEO-terms and demands. This document guides practice concerning more specific safety issues and gives, for each issue, references to more specific documentation (ie., CEOdemand-applications, overall instructions, company-group's handbooks). It is stated that the directive constitutes the guarantee of quality linkage between external demands of the reactor safety area directives (FOD) and internal company-group- and

CEO- demands and the next level of the operations control system (documentation hierarchy). In the following we will focus on the first document.

The document consists of two parts. The first part is the *general goals*, and the second is an annex consisting of a document named *Foundations to (the company-group's) general goals and attitudes toward reactor safety*. The second documents gives details of and definitions to the concepts used in the main document.
It is stated initially that the conditions at the plant regarding the technological status, competence and attitudes among personnel, and the quality of control documents are determining factors for the actual safety level. The levels of the factors can not be guaranteed during longer periods of time. In order to control the process of weakening an organization that is aware of safety, and which continuously controls reactor safety work towards well defined goals, is needed. From a safety perspective, the decisions about the existence of nuclear power lie in the hands of the surrounding world. Opinion-makers such as media or politicians often picks quite different factors for evaluating safety than the ones used within the branch, and one requirement for creating trust regarding the ways industry handles nuclear power is to avoid events, large or small scale, which may lead to that safety become questioned. A number of ambitions toward safety is identified. The development of reactor safety shall take place with the ambition to approach modern demands. Identification of possible improvements shall be carried out through a systematic safety seeking work. Introduction of actual safety enhancing measures shall be carried out as far as reasonable with reference to safety utility. All units and individuals with influence on reactor safety shall work for maintaining and developing safety culture. Available economical and personal resources shall be distributed in a way that yields a significant safety outcome.

The general goals and attitudes towards reactor safety are directed to three different areas: (1) Plant status (anläggningsstatus); (2) Competence of the personnel; and (3) Organization. Each of the areas is decomposed to a number of goals and attitudes. A summary of important aspects of the goals and attitudes for each area are given below:

Plant status

- Deterministic goals, regarding safety barriers.
- Probabilistic goals regarding goal values for core damage frequency and emission.
- Plant regeneration and technological development so that reactor safety can not be questioned.
- Ambition-level regarding analyses: Deterministic-, probabilistic, and event-analyses, are needed at all phases of the nuclear power plants annual-cycle.

Competence of the personnel

- Safety first.
- A questioning attitude and alertness regarding safety. In cases of deviations - Stop and report!
- Internal control (självkontroll). Procedures for detecting own failures and misses.
- Communication: straight, clear, detailed. To be a good listener.
- Openness: Admit one's deficiencies and understand others'.
- Commitment to safety work.

- Humbleness: About own shortcomings in a complex system and courage to show it in order to collect sufficient information and support.
- Insight regarding consequences.

Organization
- Continuous improvements of reactor safety, basically by means of seeking and attending to weaknesses in documentation, routines, competence, and the plant. And by modernizations of old constructions.
- Offensive safety work.
- A noticeable commitment, in which leaders visits the co-workers and makes safety work "visible" among them.
- Robustness in safety and sufficient safety margins or barriers.
- Sufficient safety resources to maintain safety aids and equipment on a high stable level of quality.
- Keeping documentation up to date, and guarantee quality of documentation according to established quality criteria.

3.1.4 Safety culture

Safety culture has, for some time, been recognized as central for nuclear safety (e.g., INSAG, 1991; IAEA, 1998). Accordingly, as have been reported in the policy section, above, a good safety culture is considered a key component for the safety work at both plants. NPP1 contributed with a document named *Plan of actions for safety culture* (handlingsplan för säkerhetskultur). The document gives an account of how the safety culture work is planned and carried out during a five year period. NPP2 contributed with a summary of results and an analysis of a safety culture questionnaire. The document gives information about a method to measure safety culture.

3.1.4.1 NPP1 – Safety culture "plan of actions"

The action plan is valid for a five year period and is updated twice a year. A long-term commitment is a sufficient factor for success in such a thorough process. It is crucial that the safety culture work is part of a systematic and long-term safety work pursued by the management. In order to collect reliable data concerning possible deficits and weaknesses, and to detect changes in the company's safety culture two investigations per year are carried out, one quantitative survey and one qualitative interview. The results serve as basis for the safety culture work. Examples of such work are: training, coaching, seminars, and integration-work. The demands on a good safety culture are firmly established in two documents, the company's safety policy (see separate section above), and the strategic plan.

Routines
The management system (ledningssystemet) is one of the most important tools for risk control at the company. From a safety culture perspective, deviations from the management system must be handled I two ways. First, the system and adherence should be analyzed regarding the potential for improvement. Second, measures should be taken to assure that such improvements are been carried out.

One important part of the safety culture work is to follow up the actual behavior registered as event data, such as, LER's, MTO investigations, and other reports containing deficit safety culture. It is the content of and not the amount of reports that matters.

Important agents for the safety culture work at the plant are: (1) a safety culture coordinator designated by the safety department, coordinates all activities regarding safety culture, (2) safety culture ambassadors (10 persons), who contribute with both practical and theoretical knowledge, and (3) the safety culture council, an advisory body. The council meets 4 times a year and when needed. The document identifies the persons at the different positions.

The safety culture work generates a number of standpoints. Those issues are, if needed, prepared at the council for subsequent decisions. A follow up and evaluation of the safety culture work and the methodology is presented in an annual report. Brief reports of the safety culture work are compiled twice a year.

The foundations for activities
A number of sources for safety culture in-data are stated in the document. The safety department is responsible that a quantitative safety culture survey and a qualitative interview is carried out and reported annually. The results from the survey are discussed in workshops, and the results and planned actions from the interview are communicated to the entire organization in cross-group seminars. There are also some other sources for in-data, for example, MTO investigations and event data.

Safety culture activities
There are two main categories of safety culture activities. First, there are so called *general efforts* (allmäna insatser) in which all employees at the company shall participate. The purpose is to increase the understanding about which possibilities people have to influence safety, and to create individual reminders to, by routine, bring up safety issues on the individual's personal agenda. The general efforts are: (1) workshops, (2) cross-group seminars, and (3) general training efforts.
Second, there are so called *directed efforts*. Upcoming weaknesses in the annual safety culture investigations shall be handled by means of directed efforts. Some examples are: directed -learning, -training, -seminars, -coaching, etc.
Other activities are: *Integration-work* (integreringsarbete) in which the understanding about safety culture can be increased through a system theoretic perspective. This implies for example integration of human, organizational, and technological parameters and their individual and combined contribution to safety. Still another activity is the introduction of newly employed personnel, including thorough safety training.

In an annex to the document, the safety culture work is illustrated in a schematic chart model, and in a calendar showing the months (during three years) when routines and activities are planned to be carried out.

3.1.4.2 NPP2 – Safety culture questionnaire

NPP2 contributed with a summary of results and an analysis of a safety culture questionnaire carried out 2004. The results are internal company documentation and

can not be reported here, however, the document also gives insight about the content and procedures. It consists of a questionnaire containing 57 items with fixed answer options, and one item to give a freely formulated commentary (question 58). For each question the respondent has to give his own opinion by marking a more positive or a more negative answering alternative/option. The approach of the analysis was to compare the results from similar inquiries from 2002 and 2003 in order to identify substantial changes and differences. Changes were monitored at both the company and the department level, both for the aggregated mean and for selected questions. A non-systematized summary of question-areas included in the questionnaire related to important areas of organizational safety and safety management are given below.

- Management's ability regarding explaining safety goals and objectives, convey reactor safety priorities, run reactor safety development, "double messages", encouragement of individuals to be a part of reactor safety work, clearness.
- Company-groups prioritizing of reactor safety, conveying of environmental issues.
- Department managers "visibility" and commitment at own department. Closest managers - .
- Managers' ability to show in action that quality of work is more important than speed.
- Definitions of responsibilities regarding reactor safety.
- Efficiency of experience- and knowledge transfer form events regarding annual revisions. Organizational learning and transfer of experiences. Within / between blocks.
- Managers rewarding and blaming.
- Information about operational control system.
- The relation between own department, and the quality and safety functions.
- Communication between production-maintenance.
- Development of safety culture during the last 12 months.
- Awareness of the policy.
- Possibilities for personal development in work role.
- Territorial thinking hindering communication.
- Climate between co-workers, between units at the block/department, production/maintenance vs. technology departments.
- Openness/discussion between colleagues regarding own weaknesses.
- Evaluation about performed actions, carried-out measures.
- General order at work place.
- The importance of own work to reactor safety.
- Access to external experiences.
- Quality of documentation, appropriateness of instructions.
- Silent acceptance of "short-cuts", violations of safety rules
- Well-being at work
- Groups prerequisites to take part of the environmental work. Own knowledge to take part of the environmental work.
- Importance of company's investment in environmental work.
- Information and feedback about results from quality audits and MTO-analyses.

- The departments/staffs ambitions to find root-causes to events with significance to reactor safety.
- Sufficient manning.
- Closest managers' follow-up's of decided measures.
- Time resources during revisions/non-revision to have sufficient quality of work.
- Knowledge about the principle of defense in depth, knowledge about barriers.
- Own ability and the work group's ability to keep ahead of work and planning.
- Clearness about own work tasks and responsibilities.
- Tendency within own work group to stop and report when something that might threaten reactor safety is detected.
- Application of internal control (självkontroll) for example STARK.
- Tendencies to stress.

3.2 The interviews with two Swedish NPP´s

3.2.1 Organizational change, structure, and safety

Two important organizational change processes have recently been carried out at NPP1. In 2001 the prior block separated maintenance departments were gathered in one common maintenance department. In 2002 a further reorganization was performed. This one affected all departments at the plant except the maintenance department. One important reason for the restructurings was to centralize the resources in order to achieve increased availability. The new organization enhances the sense of a unified company, and besides, it also saves some money. As one consequence of the restructuring the number of managers was decreased with 30 persons.

NPP2 has been involved in two organizational change processes during the recent years. The first (in 2002), was a large-scale organizational restructuring process involving, foremost, an integration of two plants into one company. The restructuring was carried out following a resolution from the Swedish government, and it affected large parts of the former organizations. One important result was an integration of support functions, mainly *maintenance* and *security* (skydd), functions that previously had been block-bound.
The second organizational restructuring (in 2005), comprised a parting of a former department, including both *Project and Cyclic* activities, into two separate departments of *Project* and *Technology*. The most important motive that promoted the organizational restructuring was to achieve a managerial focus on *one* business activity for each department. This restructuring affected about 300 employees. SKI´s procedure for organizational change (rutin för verksamhetsförändring, 60 items) is demanded for such projects and an organizational change plan was developed accordingly.

Important effects on the safety work at NPP1 following the reorganizations were also depending on the fact that all type-departments were gathered under one umbrella each. The possibilities for dialogue across the blocks of the plant increased. Before the

reorganization, the block specific activities were focused to a higher degree. People has still generally their work localized to one block, but are called in to support the work at another block, for example during revisions. One important benefit here is that the exchange of experiences between blocks increases, which is important not at least regarding knowledge transfer within the organization (see separate section below). However, the blocks are separate entities and are actually located at a small distance which puts some limitations to full integration of management of work, for example, when the department manager is located at one block and the work is performed at another block. From a safety perspective, the major improvements following the reorganizations at NPP1 were that clearer information channels could be created through the changes of the organizational structure, and, that a uniform company perspective on the ways of working was created.

The organizational restructuring did not entail any nuclear safety threats to NPP2. It was pointed out that it is important to plan the change process so it will not inflict disturbances to revisions. It is also important that employees have focus on their safety work, and not have to divide their attention between two different tasks, the revision vs. the organizational change process. It is also important from the managerial perspective to make one self assured that the personnel understand what is demanded with reference to the organizational change, and how it will affect their own roles at the plant, so they do not feel insecure during the change process.
With the ideas above in mind, selected key persons were interviewed so that all operational areas affected by the reorganization could give their remarks about the reorganization. The interview answers were compiled and analyzed. The co-operation with the unions was positive, and adjustments of the reorganization plan according to the *Co-Determination Act* (MBL) were also managed in a positive way.
In hindsight, it was considered that it had been better if the *safety officers* (skyddsombud) had been brought into the process earlier than they actually did.
It was narrow margins for the change plan, and many high demands were put on what to be achieved with the restructuring.
The *Environment and Safety staff* is an important organizational structure for safety work. It consists of 20 persons and supports the CEO with controlling about safety and environmental issues. It is a demand from SKI to have a detached control structure within the organization. It consists of three units: one that handles safety and consists of persons with operator background, one that handles quality issues, and one for environmental and radiation issues.

The interview with NPP1 did not reveal any specific actual or imaginable threats to the safety work related to the reorganization, but, there were other problems. There is always some degree of uncertainty related to organizational change and what it will bring back in the future. People did express some degree of worry before the reorganization. There were also some expectations of efficacy that were not fulfilled, for example, regarding the managers that were removed in the new organization. The organization pushed the organizational change by itself and had to learn from own decisions and some things had to be adjusted afterwards. One issue that had to be dealt with was emerging role confusion when the established roles of specific actors changed with the change of liaison routes, this, partly because that the responsibility of various tasks was moved between actors of the organization. The assistants were also reorganized from their different areas of activities in the former organization, to be gathered in an own unit in the new organization. The secretary work is important and

the new order regarding the organization of the secretary functions was also perceived as a little shaky in the beginning.

From a safety perspective, it is important that the production units deliver what is demanded from the owners, and that work has become simpler and clearer with the new organizational structure. In the interviews with NPP2 a systemic description of such an orderer – deliverer (customer – supplier) system was discussed (illustrated in figure 3). From a system perspective, orders are made on a structural level of the system. Deliveries are also made on a structural level. Some structures order and other structures deliver. However, the order time, that is the time from the order is given until the work is delivered, is monitored on a process level. Attitudes seem to be important here, especially when it comes to fulfill the expectations of the system efficacy.

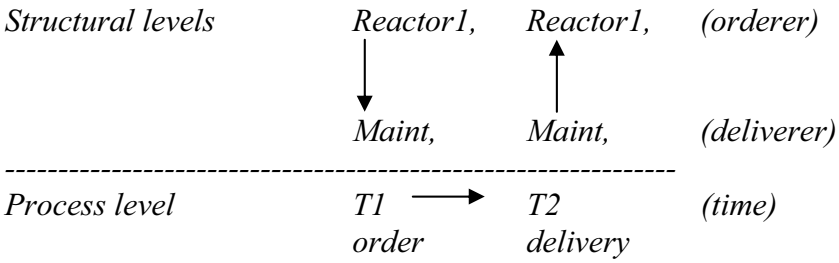


Figure 3: System description of internal transactions of work orders and deliveries of ordered work at NPP2, illustrated by a reactor that orders work from the maintenance department. The figure depicts the ordering structure and delivering structure on a structural system level, and the order process on a system process level.

Ideas for further improvements for NPP1 were discussed during the interview and pointed to a number of areas. First, the sizes of the organizational units are sometimes conceived as too large. Second, as indicated above, the distance to the chief in charge may be far when working on another block. Third, the blocks are basically different, a fact that partly is related to the development of different cultures between the blocks. Fourth, a specialization in leadership for the different areas (e.g., instrumentation) ought to be enhanced. Fifth, emerging management conflicts as consequences of obscurities in roles, especially during time pressed circumstances. For example, the manager of one operational area (resursschef) has the overall responsibility over his area, but a coordinator may have responsibility over the continuous co-ordination of work across operational areas.

No imminent organizational improvements at NPP2were in the focus at the moment. The last restructuring was finished at the time for the interview.

3.2.2 Safety threats and how the organizations manage them

A number of issues that might constitute potential internal safety threats to the own organization and which, accordingly, has to be monitored, was discussed in the interview with NPP1. One such possible internal threat is the risk to lose the opportunities for positive competence change-over (kompetensväxling), and safeguarding knowledge and experiences inherent in the organization for future benefit. Another threat is related to quick plant modification processes and a risk that one is

falling behind in the development of competence required for safe operations of the modified systems. Involvement in big projects, for example safety projects, could result in that people lose their focus on the everyday safety work. Single-competencies at top levels may pose a threat to safety at the moment when the competency (single person) is not available, or when he/she is transferred to other activities. There are risks with relying on that singular persons always should be available.

The interviews with NPP2 did not identify any explicit internal safety threats related to the own organization. However safety is part of the everyday work and some areas are more in focus at given times. Recently, various issues of *safety culture* have been important.

Also external safety threats to the organization were discussed with NPP1. One such possible external threat could be outsourced entrepreneurship. Nuclear power must rely on a strong long-term contractor market. Lack of positive competence change-over in sub contractors may pose a threat. When old, well known contractors are replaced with new ones, and there is a risk of losing experience based knowledge acquired during a long-term co-operation with the prior sub contractor company. Here, it is important that a larger part of the sub contractor's work force consist of own personnel, and not contractors from another company. Also the law governing restrictive practices (konkurrenslagen) could pose a risk, for example in such circumstances when special knowledge acquired at one plant is hindered to be transferred and utilized in the safety activities at another plant. There is, however, co-operation between companies on safety matters and operational disturbance. There are not unlimited resources for nuclear activities, and it is important to consider this fact so that some areas, pointed at from the authorities, will not get a disproportionate focus relative other areas, which result in that resources are consumed in greater extent than possible. If nuclear power is depicted as unprofitable in the long run, dangerous, or threatened by closure, this may lead to that people eschew the area, which in turn will threaten the business.

External threats from the surrounding world, including terrorist activities or dramatic economic fluctuations on the international level, were discussed. In the interviews with NPP1 it was pointed at the demands that were put on the nuclear industry to maintain strong barriers against external threats. This includes what is called security (fysiskt skydd). After 9/11, authorities have increased the demands on security and a new direction will be issued. This has brought about a large project within the company. When it comes to economical threats the company has to follow the current standards (SOA) for companies listed on the US stock market, and there has been a far-reaching work in the company in co-operation with the group.

The Interviews with NPP2 identified a few examples of scenarios that may constitute possible external safety threats. One scenario could be a future increase of nuclear power taxation. Such tax increases may lead to reconsiderations of future investment programmes, which in turn are partly related to safety.
Another issue of relevance here, are the *environmental permits* (miljötillstånd) which have been referred to the government. This procedure imposes some uncertainty about how they are going to be treated in the future. Short-sighted political decisions in general, concerning Swedish nuclear power production were also identified as possible future threats in the way they might change people's opinions and attitudes in a negative way that does not correspond to reality.

Risks related to threats emerging from the surrounding world, such as terrorist attacks were discussed. The problems are identified in many other areas and may pose a threat also to nuclear power. This is a delicate political issue which SKI is informed about and discusses with concerned authorities.

3.2.3 Systematic feedback, knowledge transfer and safety management.

3.2.3.1 Internal feedback

A number of internal information feedback channels were discussed with NPP1. Once a fortnight there is a safety board meeting (säkerhetsledningsmöte) including the plant CEO together with the managers for operations, maintenance, technology, and safety. They forward the information at their departments by means of the intranet, which means that all employees get the information. Important from a safety perspective are new editions of documentation which are distributed by Email. The documentation is available both electronically and in paper formats. It is risky to rely only on electronic documentation. If the Net suddenly gets temporarily unavailable you may stand without proper documentation. A Cross-group seminar on safety culture including participants from different departments is another forum in which information acquired in one area is shared between other areas. There are also various formal information routines; for example, that the shift manager (skiftchef) has the responsibility to look after that the most recent editions of instructions are available. The communication between the departments takes place also by telephone or by mail in cases of emergent malfunction (akut felanmälan).
Informal meetings, such as morning gatherings and coffee breaks may have some importance for communication of safety and attitudes, however, not in a controlled way. Pre-job briefings, on the other hand, are important for preparing oneself, so that the work will be performed with best possible safety and quality. There are instructions for the procedure of pre-job briefings.

A number of internal information channels were discussed in the interviews with NPP2. The company's intranet is the central information handling system. Sensitive information can be filtered out, such as individual data or market information, and for safety reasons clients have access at different levels of the system. *Management reports* and *operational control* reports (lednings- och driftlednings protokoll) are distributed via the company's intranet. The reports are accessible by all employees, and also by some contractors who are given access at some level of the intranet.
Intranet is also used in communication with company units located at distant locations, such as the company head office.

Other important information channels are various meetings. Management meetings are held 4 times per year with all managers at NPP2.
A personnel meeting with the purpose to inform all employees at the company about the operational goals, is held once a year. This effort has shown to be highly appreciated and has, for example, been expressed in the "my opinion" surveys.
There are some existing procedures in the nuclear power community for safeguarding information for the future/knowledge transfer, but they are mainly technology oriented. For example *APS*, who take charge of information from external sources (e.g.,WANO, Westinghouse, etc.).

At the plant, there are cross-groups with the purpose of communicating knowledge and experiences about specific system components, such as pumps etc.
Issues of greater dignity are discussed in the *operational control group* (driftledningsgrupp) which also handles experience and knowledge issues.

There will be an anticipated generation-shift in the near future and the company has taken some measures to manage it as safe as possible. First, the company has some level of over-recruitment in order to have a sufficient personnel buffer. Second, knowledge transfer from experienced personnel to new employees is based on a mentorship programme. General, non-formalized knowledge transfer was discussed as a natural characteristic of a large organization. For example, there is a constant mobility of personnel between subunits of the organization. The personnel that are transferred from one part of the organization to another bring her/his experiences to the new place. This holds also for management work.

In the interview with NPP1 it stood clear that no explicit formal safety indicators for organizational safety exists as such, but, there are several ways in which safety is thoroughly monitored. For example, there is a comprehensive ongoing work on *feedback from previous experience* (erfarenhetsåterföring) which gives indications on changes in risk-/safety levels, both on internationally and nationally on different levels. The task of safeguarding feedback from previous experience and knowledge transfer in general, is organized under the production department (driftavdelningen) and one person is working full-time with the task. It is demanded by SKI that experiences are fed back and safeguarded in the system. Much of the core activities at the plant consist of evaluations of changes in risk-/safety levels. Formally, it is performed by means of different forms of inspections, safety evaluations at operational meetings (driftsmöte), operational committee meetings (drift sammanträden), and safety board meetings (säkerhetsledningsmöten). It is also performed in the daily work, in all from the maintenance worker's assessments, to the company board decisions. Deviations with relevance for safety are reported in *Licensee Event Reports* – LER (Ro-rapporter). These deviations are treated at operational committee meetings and are inquired by the safety department afterwards. Moreover, it is the duty of the safety department to follow-up the organizations continuous activities of safety related matters. It is also the duty of the safety department to pull the brakes if necessary. If there are suspicions about degradation of the safety level, the safety department can perform directed inspections directed to the suspected area.
Frequent qualitative and quantitative investigations and different types of analyses for detecting eventual deficiencies are made within the frame of safety culture activities. Such tendencies are also are also captured in the continuous communication through safety culture workshops and seminars.
WANO indicators are also relevant here, for example the *availability indicator*, because they stand in direct relation to important operational goals. The goal fulfilment is monitored through the WANO indicators. Employee polls also catch problems experienced among the personnel.

There are no existing formal *organizational safety indicators* at NPP2. Existing indicators with relevance for safety are: the WANO performance indicators, RSI safety index, and the RMI environmental index. There are, however, a number of measures by which the safety thinking established in the organization can be monitored. For example, a safety culture poll has been carried out each year from 1998 to 2003, from 2004 every second year. Another example is the employee inquiry *my opinion*. MTO

investigations, quality revisions, and WANO investigations are still other examples in which organizational safety thinking is monitored.

3.2.3.2 External feedback between the NPP´s, authorities, and other companies

A number of external information feedback channels especially between NPP1 and authorities were discussed. Regarding SKI the interaction is formalized by the procedures involved in SKI's monitoring of the plant (anläggningsbevakning). There is an annual meeting between plant representatives and SKI called *SKI forum*. Before audits there are also planed meetings with representatives from SKI. Licensee Event Reports-LER (RO rapporter) is also an important part of the communication with SKI. Other more thematic fora, such as the maintenance seminar, where special issues (e.g., control-room design, etc.) are treated, are also important here. It was pointed out that the SKI's supervisory activities are generally balanced, and that it is regarded important that the good dialogue with SKI is maintained so that measures taken become motivated in a proper way.
Regarding the information feedback between NPP1 and other companies especially the co-operation with WANO was mentioned, which is both systematic and extensive. A majority of the employees are involved and it concerns most of the activities, among them indicators, peer-reviews of the activities, assist visits, various and frequent meetings, joint development of safety work, feedback from previous experience, etc. There is also some interaction with other companies, mostly various information for a, but as mentioned above, there is the law governing restrictive practices which hinders true co-operation.

Different views on plant safety between the plants and SKI was discussed. In the interview with NPP1 it was pointed at interpretations of regulations (föreskrifter). It is important that the interpreter has a thorough understanding and experience about the work regulated. It is important that SKI get people with experience from the branch. It will benefit both the authority and the plants.

Communication between NNP1 and the Swedish Radiation Protection Authority (Statens Strålskydds Institut-SSI) take place through the radiation safety manager (strålskyddsföreståndaren-SSF) who forward information and matter for handling the cases to the organization. SFF monitors the organizations duties. Weekly telephone contacts with brief status reports are also communicated between the plant and SSI. SSI makes 10 inspections a year at the company. A few theme inspections per year directed to specific areas are also performed by SSI on the Swedish plants. SSI calls together an annual SSF meeting, and arranges (when necessary) a number of seminars and discussion meetings. SSI remits revisions of both existing- and new editions of regulations to the plant. The company is demanded to report to SSI 2 bi-annual reports and 11 annual reports including, for example, doses, emissions, and how well the company lives up to SSI's demands on the activities in general. All LER's and updates of blue-prints and technical documentation is sent to SSI. There has been a very good dialogue with the authority over the years, sometimes referred to as "the Swedish model".

Other authorities that the plants have some interaction with are *The Swedish Work Environment Authority* (Arbetsmiljöverket), the related County *Administrations* (Länsstyrelsen), and the *National Swedish Police Board* (Rikspolisstyrelsen). The

interaction with the police board has increased to some degree following the new regulations concerning changes the surrounding world.

Methods for safeguarding knowledge and experiences from other technological and business areas besides nuclear power for the purposuse in the own activities (i.e., external feedback from previous experience, external knowledge transfer) was discussed in the interviews with NPP1. There are no such methods existing today, but it was emphasized that there ought to be such activities in a higher degree, for example, co-operation with civil air transportation companies on MTO issues, bench-marking together with the Swedish National Road administration, the off-shore industry, pharmacological industry, the Swedish National Defence vägverket, etc., just to give a few examples.

Regarding internal experience- and knowledge transfer, there is an ongoing project at NPP1 in which audit coordinators (revisions koordinatorer) such as production managers (driftschef), and reactor operators cooperate to find out experiences to share between the blocks regarding audits. There are also some cross-groups for *feedback from previous experience* in which more department-specific issues are discussed, for example, certain switch problems at the electrical department.

Information exchange between NPP2 and SKI was previously managed directly between the block and SKI. Now, the communication is managed between the *Environment and Safety staff* (Miljö och Säkerhets staben)and SKI. However, the blocks are unique in many ways and it requires that the blocks are involved in the discussions.

External feedback and knowledge transfer from industrial activities other than nuclear power technology was also discussed with NPP2. No formalized systems exists for such information input However, than industrial co-operation with various companies on the international market generate external knowledge that may be useful for own purposes. As an example, there is an ongoing co-operation between the own company and EDF (Electricité de France).

3.2.4 Safety analysis

The various activities within the NPP1 organization are quite stable over time and changes occur mostly on a small scale. There is still need for continuous safety and risk analyses to identify new emerging risks to safety. Overall risk analyses are performed at the company level, mostly economical analyses with focus on the stock market. At the operational level risk analyses are performed in relation to plant modifications or in relation to audits (revisioner). The tools used here are primarily the *PSA* and *HRP* methods for assessing the technological and the human aspects respectively. For preventive measures, preventive MTO was mentioned as including various measures taken to identify risks rather then estimating them.

3.2.5 Safety policy

The plants have a written safety policy about how work should be performed in a safe way. The policy document is available on the company Intranet and in print. In the

interview with NPP1 the most important aspects of the safety policy was discussed. Those aspects are (no ranking): that safety is prioritized in work, that a wrong development of work can be stopped in time, openness internally and externally, employee responsibility, and in maintaining a good safety culture which is regarded as a central concept here. Regarding decomposition of the policy into clear sub goals related to practice, there exists no such stringent dividing of the policy. A new safety polity was implemented during the time of this study.
In order to increase the establishment of the safety policy at the different workplaces of the plant, CEO and vCEO visits the different parts of the organization and talks to all resource areas about the policy ant what it means in practice. The attitude"*safety first*" is discussed continuously.
Regarding subcontractors and the company's safety policy, the contractors that work more than 3 months at the plant participate in the safety culture work. They may also participate in relevant department meetings related to these issues.

NPP2´s safety policy is expressed in the document *Goals and Attitudes for Reactor Safety* (Mål och Förhållningssätt för Reaktorsäkerhet), (200X). The degree to which the safety policy is established in peoples minds at the working sites, become expressed in the prevailing safety culture. There is a safety culture poll that illuminates the current conditions. There is a solid internal staff which is clearly rooted in a positive safety culture. In addition to this, there are a small proportion of external contractors that do not have safety responsibility.

There exists no explicit definition on the concept safety management in the organizations studied.

3.2.6 Accident and incident analysis and reporting

At NPP1 there is an internal system for reporting of safety deviations and one system for quality deviations. From one perspective, they could be considered as some kind of indicators. Regarding organizational and human aspects of the deviations, a separate MTO investigation can be initiated if the reported event includes such aspects or if there is a suspicion that such factors could be hidden in the background of the event. It was pointed out that there is deliberately no clear systematic behind the procedures of the MTO reporting, unless it involves workers safety issues. This, because leaving the doors open for anybody who might wish to initiate a MTO investigation. Deviation reports (störningsrapport) are written/reported by the shift manager, an error report is written by anybody who discovers the error regardless of position in the organization. The analyses aim at establishing the primary cause to the event which could be related to technological, as well as human or organizational factors.

Besides technological causes to incidents, the internal safety reporting system allows reporting of explanations based on human and organizational factors (MTO). The internal reporting system does not only apply to events related to traditional reactor safety, but also to safety issues in general and quality. Besides retrospective MTO event reporting, preventive MTO is reported if such an issue comes up. MTO issues are compiled on a annual basis and there is an MTO council (råd) at the plant for these issues.

3.2.7 Human resource management

At NPP1 all vacancies are not filled. There is a need for manning mainly due the large scale projects that are carried out at the moment, for example the *pulse and power increase project,* and an ongoing maintenance project. There is also an approaching "age bulb" at the plant that will lead to a further need to employ personnel. There are no indications about shortages in the manpower reserve, and there are many applicants to the jobs.

4 Concluding remarks

The interviews together with the documentation from the two NPP's, uncovered interesting examples about how important aspects of safety in practice are described by experienced Swedish nuclear power professionals. Below, important results are given in condensed form together with concluding remarks. In the end of the chapter ideas for future research are suggested.

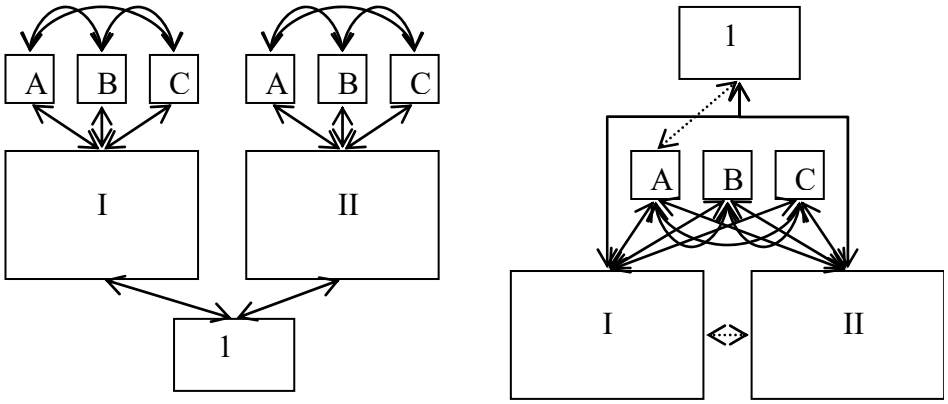
4.1 Organizational systems and change

The content of the documentation of the two organizations was clearly applicable in terms of the system theoretical framework described in the introduction. The documentation showed clearly the structural disposition of the organizational sub-systems at different levels and pointed at simple relations between the sub-systems. In addition, the organizational description document revealed interesting aspects of important control structures which gives a hint about the underlying control processes. This means that much of the processes descriptions are mapped to system structures and are not pure descriptions of processes. This is understandable, but questions also the general nature of our conceptualizations of system processes, and not at least from a safety perspective. A process approach or a structural approach to understanding may generate different knowledge, which in turn may result in different approaches to coping. This idea is developed further below. The documentation also pointed at the fact that different localizations of substructures in an organizational chart/model gives rise to different mental models regarding the organizations, irrespective of the arbitrary or practical reasons behind it. This has high relevance for safety management and systems control.

According to the interviews, the plants had recently been involved in large scale organizational change processes. The following restructuring of the organizational systems aimed, foremost, at concentrating resources by fusion of prior diversified organizational functions. One example of this is the fusion of prior block-separate maintenance departments, into one common maintenance department for all blocks. Several examples of reasons and related benefits for this centralization of resources were identified in the interviews:

- To create a clearer organizational structure.
- To create an increased focus on work.
- To create better/clearer information channels.
    - Increased dialogue/communication between blocks.
    - Increased information transfer between blocks
    - Increased possibilities for dialogues across blocks.
    - Increased feedback from previous experience.
- Uniform company perspective on work.

In terms of system structures, a simpler system structure, with increased information exchange between sub-systems is sought for. In figure 4 the prior and the new organization is exemplified schematically. Information flow is indicated by arrows.



Prior organization New organization

Figure 4: Schematic illustrations of organizations with block-bound resources (prior) and concentrated resources (new). Theoretically, the new organization allows for increased information flow across units. The new organization emphasizes possibilities to central control of common resources (example as dotted line 1-A, and interaction between blocks to coordinate resources (dotted line I-II). 1=head management level, A-C=resources (e.g., electricity, maintenance, etc.), I and II=blocks.

Uniform safety culture perspectives and safety attitudes in general may be promoted more efficiently in systems with shared resources than in systems with separate more or less autonomous sub-systems.

The reorganizations were carefully planned and consideration was showed to all parts involved. Accordingly, the reorganizations did not pose direct safety threats to safety. However, some important reminders that ought to be considered in relation to reorganization were identified:

- Worries related to uncertainties about the future experienced by employees.
- Emerging role and responsibility confusions following that people become moved around and achieve new tasks.
- Preparations of the system for making adjustments after the reorganization.
- Keep focus on primary safety task in work during reorganizations.
- Organizational change is an organizational learning process.
- The size of the organizational units tends to increase after fusions.
- The small but yet physical distance between blocks become reality when resources has to be moved around between blocks.
- There are both structural and cultural differences between separate units that have to be dealt with when they are integrated.

One good explicit example of pure system thinking related to system structures, and system processes and was revealed in the interviews. The example related to ordering and delivery between organizational units and illustrated clearly how input and output is monitored at a structural level, but the process behind it runs on a process level, or put another way, processes are detectable as changes on the structural level.

4.2 Threats

A number of internal threats to the own organization was interpreted from the interviews:

1. To lose the opportunities for positive competence change-over.
2. To lose the opportunities for feedback from previous experience.
3. Negative safety culture in general.
4. To lose primary safety focus when involved in large scale temporary projects (divided attention!).
5. Technological modifications and development are sometimes quicker than the processes of development of personal experience related to the technology.
6. To be trapped in a disproportionate reliance on single competencies.

For number 1-3 there are structural organizational solutions consisting of various programmes that are implemented at the plants. The solutions for 4-6 are not given explicitly. There need, to exist reminders along the preparations for plant modifications, and during work, related to human factors, plus an evaluation afterward. Threats of type 6 are more subtle, positive reliance is a good feature, but perhaps there also need to be diversification among top competencies, however, something that is not so easy to find. Planning of work and backup might mitigate the effects of a sudden loss of a single competence. A number of internal threats to the own organization was interpreted from the interviews:

1. Outsourcing and safety
    - Safety culture in sub contractors
    - Competence change over -//-
2. Disproportionate focus on some demanded projects consumes the limited safety resources.
3. Negative depiction of nuclear power creates negative attitudes and less trust.
4. Short sighted political solutions of the future of nuclear energy.
5. Remittance of environmental permits to the government.
6. The law governing restrictive practices hinders safety co-operation to some degree.
7. Safety threats, terrorists.

Outsourcing and safety seems to be an issue that is in the minds of nuclear power managers. The same safety related organizational problems that exist for own employees exist also for contracted workers. The difference is that the control is not fully in hands of the power plants. This threat is labeled external since companies are external, however, reasons for the control problem lays partly in hands of the customer, the power plants. This later part of the problem is in some way an internal threat to the organization. The plants have different programs to integrate external workers to the own safety work revealed in the interviews.
There are limited resources for the nuclear activities including safety. It is important that there is a sound dialogue regarding investments in singular safety projects that are demanded by the authorities. It seems also important that the plant take precautions so that the project becomes dimensioned as efficient as possible. This includes also human resources that should not have to be “divided” between tasks, but instead organized so focus is kept on the primary safety tasks in as high degree as possible. Number 3-7, are not controllable from a company perspective, but mere realities of the world of today. A positive relation to the public, openness about the own activities, and to be seen in the

debate, may contribute to maintain positive relations with the surrounding world in general.

4.3 Information and feedback

4.3.1 Information management

Nuclear system safety relies on a good information management, including availability to recent safety information. According to the interviews, both plants exhibit necessary internal information channels for an efficient information flow between the organizational units. This includes a central intranet, from which much of the relevant safety information regarding for example, new editions of instructions etc. is accessible by all employees. In nuclear activities it is regarded important from a safety perspective that instructions not only are available in electronic form, but also in print, in case the intranet becomes unavailable. There are other formal established information channels for different purposes regarding internal communication at the plant. They include Email, and telephone contacts between departments, for example, in case of error reporting and calling for maintenance etc., various planned meetings at different levels of the organization, and a number of special fora where different special problems are communicated and solved. Different protocols and reports distributed according to limited send lists or filtered in the intranet is another information communication channel. Pre job briefings are considered as very important so that the work will be performed with best possible safety and quality. Promotion of informal information channels as important was not indicated in the interviews. An annual personnel meeting in order to distribute information that is central for all workers at the plant seems to be appreciated among the employees at one of the plants.

According to the interviews, nuclear power plants exhibit well established external information channels for an efficient information flow between the organizational and external organizations. For safety information, communication with SKI and SSI are the most relevant, since they are the major regulatory instances for Swedish nuclear activities. The interview gives a good illustration about the channels and procedures behind the information flow between the companies and the authorities.
It was emphasized from both plants that the co-operation with Both SKI and SSI and which is based on openness, has been very positive during the years. A good relation between licensees and authorities is an important prerequisite of good safety work.

Cooperation with other companies is limited according to the law governing restrictive practices which hinders true co-operation. Information exchange on safety matters are however allowed and promoted. There were indications in the interview that the law may impose a threat to safety, when experience on some aspects of nuclear activities acquired at one company becomes hindered to be utilized in safety work elsewhere.

Safeguarding internal feedback from previous experience and knowledge transfer in general may be important assets for a good safety culture. There are ongoing projects indicated in the interviews, not at least in relation to future competence- and generation change over. Methods for safeguarding knowledge and experiences from other technological and business areas other than nuclear power do not exist. There were expressed a wish in the interviews that such activities should be initiated.

4.3.2 "Indications" on safety indicators

There exist no established organizational safety indicators. But a number of existing system features in which safety is monitored that include aspects of a safety indicator was discussed under the interviews. They are:

- Licensee Event Reports – LER.
- A project on feedback from previous experience which gives indications on changes in risk-/safety levels, both on internationally and nationally at different levels.
- Safety culture polls.
- Employee inquiries, such as"*my opinion*".

The above instruments are primarily used for other purposes than organizational safety monitoring. Aspects of LER's could be a part of a safety monitoring system, for example as base rates for certain event types. This needs an extensive development including data base integration, might be interesting for a future project (see Salo, 2005, for a discussion about this matter). Structured continuous polls could also be designed for organizational safety indication. One very important prerequisite for such developments is, again, a theory that integrates organizational and human factors with technology, such as a system theoretic frame. This is discussed further in the end of this chapter.
Some other safety indicators exist, but they are indicators that are directed to the technology and production in a higher degree than to the organization. They are: WANO indicators, for example the *availability indicator*; and, RSI safety index, and the RMI environmental index. It is indicated in the interviews that much of the core activities at the plant consist of evaluations of changes in risk-/safety levels.

Regarding safety culture, the documentation showed that the safety culture work is well established at the plants. The methods are comprehensive, long-term, and far reaching. The work has an holistic approach in the way that all personnel and all parts of the organization shall participate in the safety culture work. The goal is to promote a good safety culture in all aspects of work, and one step toward success is the personal understanding the interplay of its own role and others roles in the system. Consequently, the approach to safety culture work was well adapted to the general system theoretic approach. The procedures were efficiently structured and individual and organizational participation in the administration of the work were identifiable in the documentation. For the interested reader the chapter gives many ideas both to the practical organization of safety culture work, and to the monitoring of safety culture.

4.4 Policy

A company's safety policy is important and expresses the general aim for the safety attitude. Both plants have not only a general policy text, but also decomposed specifications for a number of sub-areas, plus explanations or interpretations of the policy. In one policy document analyzed it was stated that it constitute the linkage between external demands –internal demands – and the control system. The final part, resembling the control-documentation level, was clearly specified with references to actual documentation. This approach to policy is also an example of system adjustment. Ideally, the policy is identified structurally in relation to system sub structures, the

process behind control is clarified, and relevant actions are planned in advance. The content of the policy documents regarding relevant issues in large did not differ between the plants. Much of this is regulated on the national level. However, the documents pointed at different ways of representing the higher order categories of the policy issues. Categories from one plant contained more process related categories (for example, striving for safety culture, continuously working with safety) and the other more structural categories (for example, plant status, competence level). Both ways are relevant, but as with general representations of the organization (above), it may lead to different mental representations and following (different) ways of coping.

Methods for implementing the policy was illustrated in the interviews, for example, management visiting the workplaces for discussions of what the policy means in practice. The plants have not decomposed the safety policy into measurable safety goals. A decomposition of goals might be guided by the general system safety approach as in other safety work. Integration of policy, goals, monitored by indicators, can only become true if a common model is applied to safety work in general. Examples of important aspects of a safety policy expressed in the interviews are:

- Safety is prioritized in work.
- A wrong development of work can be stopped in time.
- Openness internally and externally.
- Employee responsibility.
- Maintaining a good safety culture.

No explicit definitions of the concept of *safety management* exist at the plants interviewed.

4.5 Future research

Outsourcing may not only pose an external threat to nuclear power plants. The ideology behind outsourcing and the consecutive planning for contractor activities lays partly internally, in the management of nuclear capital and safety. One of several reasons for outsourcing is to not keep special resources bound as capital at the plant, however, safety is an integral part of all activities and maximal control over safety requires that the company has its own hands on the activities. We suggest that extensive research is initiated to find tools for improving safety in nuclear power plants in relation to outsourcing and external sub contractors with safety relevant duties at the plants. One interesting initial approach may be to define the boundaries of the safety system, how outsourced companies become a sub structure to the safety system, and the system could establish control of such additional system structures. Another interesting question is how temporarily added substructures, such as sub contractors that work at the plant for a short time, shall be counted to the safety system.

We guess that it might be important to more than once consider what the benefits from a restructuring will be in terms of system efficacy. Benefits from reorganizations are often

modeled in monetary terms. Fewer smaller units are cheaper! Many organizational systems of today are already streamlined in many aspects. The possibilities to find a more efficient system solution by merely moving, merging, or dividing a limited number of sub structures, become harder the more optimized the system already is. This structural approach to system optimization of organizations is perhaps the one that is easiest to imagine. But, there might be other solutions that are more efficient. To consider process solutions in a higher degree might be one way to change perspective to organizational change. We think it is important from many perspectives to devote some future research to investigate new approaches to organizational optimization in contrast to traditional restructuring.

System thinking is an important part of technological reasoning. Nuclear power engineers master this when talking about their systems from a technological point of view. However, when switching from a technological discourse to an organizational or human, despite the focus of the issue (safety, management, etc.), professionals seems to release from the stringent theoretical coupling. In relation to organizations and human issues it seems as if there is a greater tolerance that various perspectives could be put on the problems discussed. There need not to be a conflict between a systems approach to human and organizational issues on one hand, and other models derived from psychological, organizational, or managerial theories in general. They constitute explanations on different levels of abstraction. However, in the moment we wish to integrate technology, humans, and organizations for some purpose, we also need a general framework in which all these aspects can be discussed with some common denominator and transferable concepts. This might also be a good approach to develop the basis for organizational safety indicators. An indicator must be a stable feature of the system, a feature that is not changing over time, in order to produce valid and reliable data over time. The system approach is suitable for these purposes. This seems to be an important issue for us who are working more with human and organizational issues than with technological. There has been an ongoing development of theory regarding safety culture in general that is beneficial for industries, but there are still many other areas that need to be investigated. We which that the general system theoretic framework (Svenson and Salo, 2004; Svenson, Salo and Allwin, 2005) will inspire future research in all areas regarding the interaction between humans, organization, and technology.

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Appendix

Interview structure

(1) Verkets organisationsstruktur och säkerhet. Förändringsprocesser:

1.1 Har organisationen nyligen genomgått någon form av omorganisationsprocess?
1.2 Vilka delar av organisationen var berörda av omorganisationen?
1.3 Vilka var de viktigaste anledningarna till omorganiseringen?
1.4 Vilka var de viktigaste effekterna för säkerhetsarbetet efter omorganisationen?
1.5 En omorganisering kan vara resurskrävande Vilka hot kan detta medföra för säkerhetsarbetet (som i och för sig inte behövt inträffa)?
1.6 Från ett säkerhetsperspektiv, vad är bra/bättre i den nuvarande organisationens struktur?
1.7 Finns det ytterligare förbättringar som ni ser kan göras i organisationen som gagnar säkerhetsarbetet?

(2) Hot mot säkerheten och hur dessa hanteras.

2.1 Vilka är de väsentligaste interna riskerna för organisationen som ni själva upplever det?
2.2 Vilka är de väsentligaste externa riskerna för organisationen som ni själva upplever det?
2.3 Riskbilden kan ha förändrats på senare tid i och med omvärldens förändring (ekonomi, terrorattacker, etc.). Uppmärksammas dessa former av externa hot i säkerhetsarbetet? På vilka sätt?
2.4 Finns det några indikatorer för förändringar av risk-/säkerhets nivåer?
2.5 Finns det metoder för att uppskatta sådana risker?

(3) Informationshantering och systematisk återkoppling.

Intern återkoppling (inom organisationen):

3.1 På vilket/vilka sätt förmedlas informationen om säkerhet mellan organisationens enheter? Sker informationsgången på samma sätt mellan alla enheter – gemensamma informationshanteringssystem?
3.2 På vilket sätt förmedlas informationen om säkerhet mellan geografiskt olika lokaliserade enheter?
3.3 Vilken roll spelar informella möten, t.ex. kafferaster, morgonträffar?
3.4 Finns det system för att tillvarata och återanvända kunskap inom organisationen (Erfarenhetsåterföring/Knowledge transfer)?

Extern Återkoppling Verket - SKI – Andra myndigheter (SSI, Arbetsmiljöverket, etc.):

3.5 Hur sker informationsutbytet mellan verket och SKI (och andra myndigheter relaterade till kärnkraftssäkerheten)?
3.6 Sker det någon kommunikation mellan verket och andra verk/bolag – på vilka sätt?

3.7 Finns det olika sätt att se på säkerheten hos verket, och SKI, vilka är i så fall det största skillnaderna och ev. svårigheter med dessa olikheter?
3.8 Hur ser kommunikationen ut mellan verket och andra myndigheter, (icke direkt relaterade till kärnkraftssäkerheten - t.ex. Naturvårdsverket)?
3.9 Sker det kontakter direkt med något departement – i vilka frågor?
3.10 Kan ni se några metoder för att tillvarata kunskap om säkerhetsarbete från andra verksamheter utanför kärnkraftsområdet och använda den inom den egna verksamheten (Erfarenhetsåterföring/Knowledge transfer)?

(4) Säkerhetsanalys och händelserapportering:

4.1 Befinner sig organisationens verksamheter i en ständig utveckling eller är verksamheterna relativt stabila över tid?
4.2 Finns det behov av kontinuerliga riskanalyser av organisationens verksamheter för att identifiera nya risker - metoder?
4.3 Beskriv händelseförloppet för den interna rapporteringen av en incident.
4.4 Vem skriver dessa incidentrapporter?
4.5 Vilka krav på kvalifikationer ställs på rapportörerna?
4.6 Hur ser dessa rapporter ut? Finns det möjlighet att ta del av en rapport?
4.7 Finns det utrymme i rapporterna för orsaksförklaringar till incidenten avseende människa, teknik, organisation?
4.8 Skiljer sig den interna rapporteringen av en incident från en rapportering av en olycka/haveri
4.9 Hur utvärderas interna händelserapporter av organisationen?
4.10 Ge exempel på konsekvenser som kan följa på utvärderingen av en händelserapport.

(5) Säkerhetspolicy:

5.1 Finns det en formell skriven säkerhetspolicy inom organisationen?
5.2 Hur är organisationens säkerhetspolicy relaterad till det praktiska säkerhetsarbetet?
5.3 Vad upplever ni som viktigast i organisationens säkerhetspolicy?

(6) Reglering av aktivitet:

6.1 Hur skulle ni beskriva SKI´s regleringsstrategi?
6.2 Hur är SKI´s reglering av verksamheten kopplad till det interna arbetet med ledning för säkerhet?
6.3 Vilka åtgärder kan ni tänka er för att ytterligare förbättra sambandet mellan SKI´s reglering och det egna säkerhetsarbetet,

(7) Bemanning inom organisationen:

7.1 Är alla tjänster tillsatta inom organisationen – Finns det vakanser?
7.2 Finns det behov av att utöka personalstyrkan, men som man pga. olika omständigheter (ekonomiska etc.) inte har möjlighet till att genomföra?

(8) Begreppet säkerhetshantering (safety management):

8.1 Finns det en uttalad definition på begreppet säkerhetshantering (safety management) inom organisationen?
8.2 Hur är policyn förankrad ute på arbetsplatserna (attityder, nedbrutna mål)?
8.2 Hur är policyn förankrad hos underleverantörer (attityder, nedbrutna mål)?

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