Organisational factors and nuclear safety – issues to address in research and development

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***Abstract*— The influence of organisational factors on nuclear safety has been identified in several studies. In spite of their importance no integrated approach to address them seems to have emerged. The paper starts with issues identified in the LearnSafe project to discuss how they have been addressed in research and development within Finland and Sweden and discussed their importance in a larger frame. This discussion is used to suggest a research agenda for what could be called a midfield approach, where utility and regulatory needs could be combined. The paper serves at an introduction to the discussion part of the special session on Organisational learning and learning organisations – the LearnSafe project three years after.**

I. INTRODUCTION

The LearnSafe project (Learning organisations for nuclear safety) was started in 2001 and it was successfully completed in 2004 [16]. The project investigated processes connected to management of change and organisational learning at nuclear power plants across Europe. The focus of the project was on tasks and activities of senior managers, who are responsible for strategic choice and resource allocation. This focus was selected due to the importance of senior management decisions, approaches and attitudes, which have an influence on the safety and economy of the plants.

The LearnSafe did not find a direct continuation, but the five main partners continued research and consulting in the broad field or organisational factors and their influence on nuclear safety. This paper collects especially issues that have been on the table in Finland and Sweden over the last three years. As a conclusion the paper summarises some emerging issues that could be in focus for the research in the years to come.

II. LEARNSAFE SPIN-OFF ACTIVITIES IN FINLAND AND SWEDEN

In Finland and Sweden the LearnSafe partners had the advantage of an earlier co-operation that had stretched over many years and had created open and trustful relationships. This relationship between the researchers and the nuclear utilities was capitalized in the LearnSafe project to initiate small targeted efforts investigate a few issues that were considered important. These activities have been reported only internally in the LearnSafe project and they are therefore summarised briefly below.

A. Organisational structures

1) Quality systems

Early quality systems were usually seen as separated from the management system, but today they are often integrated into them. On a very basic level the quality system may be said to contain defined quality requirements for work activities together with descriptions of how that quality can be reached. The quality system also specify regular audits of important activities with the dual purpose to ensure that activities are carried out according to requirements and that possible quality deficiencies are identified, corrected and prevented in the future. One important function of the audits is to produce objective information for review by the senior management. The quality system also contains a description of used practices for keeping the system up-to-date. The quality systems are sometimes seen as an administrative barrier to prevent work of inferior quality.

2) Operations management

Operations management is directly concerned with the responsibility for nuclear safety as imposed by the legislation. It is therefore the most crucial activity at the plants and should therefore be structured with very clear authorities and responsibilities. Operations management is typically delegated in steps from the responsible manager to a unit manager and an operations manager. The operations manager acts as the superior for the operational shifts consisting of the control room operators and other operators. The shifts have a 24-hour duty according to an agreed rotation schedule. To compensate for vacations, training, sickness and other duties the number of shifts is typically six or more per unit. The number of operators on a shift is typically 3 operators in the control room, whom are further supported by 3-5 field operators. The shift supervisor acts as the leader of the shift team.

3) Process orientation

Thinking of work activities as processes is a relatively new management concept, which was introduced to ensure a smooth flow of errands between organisational units. Structuring work activities as processes places a special focus on the handing over of outputs from one work activity to form inputs of another work activity. Looking at interconnected work activities gives the benefit of considering them as an entirety, which has certain goals and uses common resources. Many nuclear power plants have initiated projects to investigate the applicability of the process concept as a way to structure work activities. Generally

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there is a large agreement that the concept is useful, but there is a larger divergence in views how the process concept should be reflected in the organisational structure.

B. Core competency

The concept of core competency is a topical issue in many organisations and has been used by many consultants to support the strategic planning processes connected to human resources management. One practical use of core competency at the nuclear power plants has been to separate between activities in an organisation that can be outsourced and those that cannot.

1) A study within the LearnSafe project

A small study to investigate how the concept of core competency was perceived and used at two nuclear power plants was carried out during 2003. A total of 15 persons from different organisational functions and levels participated in structured interviews of about 1,5 hours.

All respondents viewed core competency rather similarly, although minor differences in the emphasis could be felt. Different dimensions of core competency have been identified and one level one could separate between competencies needed in the functions of operations, maintenance and technical support. Another division could be found according to technical, intellectual and cultural assets. Many respondents pointed to the need for both breadth and depth in the competency, which is related to a distinction between specialists and generalists.

In a more detailed discussion of competencies in various fields many respondents pointed to the need of a thorough understanding of plant systems, their functions and how they are operated and maintained. Within the area of management the needs for and components of enlightened leadership have to be understood and acted upon. As a counterbalance to the need for formality and accuracy, there is a need for creativity and flexibility. The plants themselves cannot have all competencies in their own organisation and therefore the concept of an intelligent customer has been coined. The placement of competencies to physical locations and within the organisational structure is important for internal communication.

The most crucial competency in the nuclear industry is to understand when the plant is in a safe state to enable responsible managers cannot make correct operational decisions. Due to the complexity of the plants it is necessary to have clearly defined operational regimes, where decisions on an hourly and daily basis should be based on clearly defined rules and instructions. The so called MTO concept (man, technology, organisation) has in the nuclear industry been coined to underscore the need for a systemic approach to safety. This concept is stressing the importance of a broad understanding of interactions between technical systems, people and the organisation.

2) Maintaining core competency

Definition of core competencies is closely connected to the strategic planning process. Respondents found it valuable to define core competencies as explicitly as possible. They also saw the benefit of engaging a broad participation from the personnel in the definition process. Several respondents reported that a participation in discussions of core competency over organisational borders had proved to be useful in creating a better understanding of interconnections between various tasks.

The nuclear power plants in Finland and Sweden have carried out competency surveys in which present competencies have been documented and the need for competencies in the future has been assessed. Respondents stressed the need for making the competency surveys systems operational and used at all levels in the organisation. Managers are responsible for the work their subordinates do, i.e. that they are competent and that they carry out work according to specifications. Over the years has been a slight transfer from the organisation to the individuals in the responsibility for a continued competency development.

Core competency is associated with competency that a company should have within its own organisation. The decision to produce or buy is always a matter of strategic considerations and there may be different reasons for producing or buying some services. The respondents agreed to a large extent on these general principles and some of them pointed to the difficulty especially for specialists to maintain their competency without a continuous interaction with other specialists in their own field.

Recruitment and training programmes represent one important part of human resource management. Presently the nuclear power plants in Finland and Sweden are engaged in managing a larger renewal of the personnel, which is due to an upcoming wave of retirements. The need to transfer tacit knowledge from the old generation to the newcomers has been identified. In Finland the new plant project has created a large enthusiasm and many new people have been and will be recruited to the nuclear field.

The training of managers was brought up by many respondents. There was a large agreement that the pressure on managers has been growing over the years and that persons entering a management career within nuclear power would need more systematic training today than before. This would in addition to a broad technical training also include training in leadership, communication and safety culture. In the discussion of management training some respondents noted that technical excellence is not always a good predictor of leadership excellence.

3) Core competency as a strategic tool

A use of the concept of core competency supports sense making in organisations. It is closely connected to the mission of the company and it becomes an important part in the development of plans for the future. Combining a top-down view in considering core competencies in a strategic context with a bottom-up view from performance appraisals and competency surveys helps in ensuring that plans are laid on a solid ground.

Companies often consider competent and motivated personnel as their most important asset. This is even truer in the nuclear industry, because a continued operation relies on skilled and competent personnel in operating and maintaining the plants. The deregulation has placed a higher pressure to be cost effective, which has introduced the need for achieving more with fewer resources. Customer orientation has been one of the catchwords in the conventional industry. The nuclear power

plants do not have customers in a conventional sense, but have instead important stakeholders.

One important task for managers at each level in the organisation is to create motivation. Delegation and empowerment have been used as means to increase motivation. The creation of ownership especially within maintenance is an issue in which Finnish and Swedish nuclear power plants have invested efforts.

Both in Finland and Sweden there are ongoing changes in the educational systems. One change is the gradually increasing share of the age cohort that is selecting an educational path towards higher college and university studies. It would therefore be important for the nuclear power plants to be able to utilise the higher educational level in the age cohort, which may need the definition of new professional roles.

Another profession of large importance is internal inspectors and reviewers. They have to be generalists in a true sense of the word and they should have a very good understanding for how safety is constructed into systems, work practices and instructions.

Vendors and contractors serve as natural partners for co-operation with the nuclear power plants. The annual refuelling outages can for example involve hundreds of companies and over thousand persons. Contacts between nuclear power plants, which aim at a sharing operational experience is an important mechanism. Important co-operation also takes place through the international organisations such as WANO, IAEA and OECD/NEA. Finally the nuclear power plant in Finland and Sweden have long traditions of contacts to educational and research organisations.

C. Organisational change

In the LearnSafe project two cases of organisational change was investigated more closely. In one of the cases a nuclear power plant took a new organisational structure into operation. In the other case two utilities were merged into one.

1) The path to a new organisational structure

A study of a large organisational change that took place in the period from 2000 to 2002 was carried out at one of the Swedish nuclear power plants. The need for an organisational change had become apparent in the late 1990ies, because three different cultures had gradually emerged at the three unit site. There were also some overlaps between the three units and many expert groups were undersized. The deregulation of the electricity supply had also demonstrated that a sustainable safe and economic operation needed a higher efficiency in the activities.

A first step in the move to a new organisational structure was taken in the reorganisation of the maintenance activities at the site. Before the reorganisation maintenance had been divided into four departments, one for each unit and the fourth one for common activities for all three units. In the reorganisations four new departments were formed, which served all three units. The four departments got a functional division, where one was responsible for mechanical maintenance, the second one for electrical and I&C maintenance, the third concentrated on maintenance methods and the forth services.

The next step in the reorganisation was very much larger and it was therefore preceded by a large effort in planning and preparation. The overall goal for the organisational change was defined in several working groups. These working groups finally involved nearly 10 % of the whole personnel for the search for and definition of more efficient working practices. When the organisational structure gradually emerged the managers for the organisational units were appointed and were given the task of forming they own groups of people. The regulatory notification was filed when the most important managerial positions had been filled.

The new organisation was split between two main responsibilities, one for the plant and the other for the personnel. The basic idea with this division was that plant owners would ensure that the technical conditions of the three units were looked after carefully and that the resource organisation would supply the necessary resources to the plant owners. The resource organisation was divided into operations, maintenance, technical support, safety and environment, finances personnel and communication. To ensure the necessary co-ordination between the three units on the site co-ordinators for operation, maintenance and technical support were assigned for each of the three units.

At the time for the study about 1,5 years after the introduction of the new organisation, there were still indications that the organisation had not yet settled completely. However some of the initial fears that were expressed had clearly not materialised. The co-ordinators got a very important role in the new organisation and the positions were manned with very experience persons.

The new organisation had very clearly created a platform for a unification of practices at the site. It was also easier to find a consensus on questions that in the old organisation had created a lot of discussions. In spite of a generally positive view on the organisational change some difficulties were also mentioned, but they were mostly connected to issues, which were expected to improve with time. Some places were additional fine-tuning of the organisation were also identified.

2) An organisational merger

The political shutdown of the Barsebäck 1 nuclear power plant in Sweden led in the end to an organisational merger of Barsebäck 2 into the Ringhals organisation. This merger was studied in the LearnSafe project as a case to create an understanding of factors that influence the success of organisational mergers. The study was based on results from an organisational questioner and structured interviews with a total of 10 persons from both organisations. In looking at the two sites, there are evidently more similarities than differences, because both organisations operate in Sweden

D. Organisational controllability

Researchers in the LearnSafe project were at one of the Swedish nuclear power plants challenged to discuss organisational controllability. The question was formulated after an informal discussion of means that managers have in controlling the development and actions of an organisational unit for which they have been given responsibility.

1) Concepts of controllability

The concept of controllability carries the concept of a system that has to be controlled by an input to bring about a certain

output. Controllability has been defined formally in systems engineering and it involves the concept of a state and the existence of an input, which transfers the state of the system from an arbitrary initial state to the zero state. Controllability also carries the concept of an objective for control, i.e. there are some outputs that are considered better than others. Control assumes the existence of an actor, who controls the system through own actions or by intermediate agents or artefacts.

Control of organisations has been studied in the management sciences and a vast literature exists on guidance for managers in their task of controlling organisations. Organisations become efficient through their division of labour. Specialisation requires co-ordination, which is one important managerial task. Control in organisations is executed through cycles of planning on a strategic and an operational level. Management of organisations involves various decisions to be taken in response internal and external events. Organisations can never be controlled like machines, because they are composed of actors with their own will. This implies that two modes of control can be identified, where the first is the conscious control exercised by the management and the second is a kind on self-control exercised by the members in the organisation.

Various psychological mechanisms of controllability can be identified in organisations. One is connected to situational awareness, where the state of an organisation is triggering its members to certain control actions. A second is motivation, where members of the organisation seek meaningfulness in the work they do. Capabilities, attitudes and beliefs are major influencers on the quality of work people do. Psychological research has shown the importance for people to find themselves in control of their own situations. Control actions between managers and the controlled organisation are mediated through direct orders and more indirect persuasion. The organisational culture is an important component of controllability through norms and rules of behaviour.

2) Control of safety

Organisational controllability is an important concept in considering the control of safety oriented organisations. Managers have to understand that the control they exercise is mediated by everyone in the organisation, which means that the control they exercise is built through images and artefacts. The images have to be communicated and the artefacts have to be adapted for their purpose. In setting goals and expectations the managers have to realise that the control is exercised through people, which implies that the receivers of control signals should be able to interpret their meaning and convert them to actions.

Organisational controllability is in some respects opposite to organisational stability. A large organisation can have a large inertia that is preventing change, but very frequent changes may impede the organisation by causing its members to feel that they loose control of their own situations. An understanding of organisational controllability relies on a combination of systems thinking the use of models from management science and the behavioural sciences. Senior managers have a key role in creating preconditions for organisational controllability, which would involve elevating visions and enlightened leadership.

III. NATIONAL RESEARCH ACTIVITIES IN FINLAND AND SWEDEN

The national research activities in Finland and Sweden are organised in slightly different ways. Finland has a long tradition of publicly funded research programmes in nuclear safety. In Sweden the public research in nuclear safety is funded by SKI in research projects that are only loosely co-ordinated.

A. The national Finnish research programme SAFIR

The Finnish national research programmes have been characterised by a broad co-operation between universities, research organisations, utilities and the regulator. One specific objective of the Finnish national research programmes has been that they should support the maintaining and development of nuclear competency in Finland. The last four year SAFIR programme was brought to an end in 2006 (cf. [14], [10]) and a new programme has been formulated and started [4]. Both the old and the new programme addressed the broader area of the influence of management and organisation on nuclear safety.

1) Human-system interfaces

The project aimed at formulating methods for the evaluation of human-system interfaces of complex industrial systems. The project anticipated the needs of both utilities and the regulator in the modernisation of the four Finnish nuclear units that are in operation. Results of the project have also been utilised in the activities connected to the new unit being built in Finland. In the project operator experiences on working in screen based control rooms were collected. The management of design processes from a human factors engineering point of view was also addressed.

The project will be continued as a part of the new programme with more detailed investigations of the use of large screen displays and computer based procedures. More specifically the research will investigate the use of information rich displays and how they are used in diagnosing disturbances. The hypothesis was that the new ways of presentation information will support the formation of new knowledge structure for the operators. One subtask of the project will be aimed at investigating the operability of hybrid control rooms.

2) Organisational culture

The influence of organisational culture on nuclear safety was investigated from different points of view. One part of the project assessed the maintenance organisations in two Finnish and one Swedish nuclear power plants [9]. Another part made an assessment of the safety culture of the engineering organisations responsible for the construction of the new plant in Finland. A theoretical part of the project discussed the drift of organisational practices and norms towards unsafe conditions. Within the frame of the project a literature review of safety critical organisations was also carried out [8].

This project will in the new programme be followed up with a study, which more broadly is addressing safety management and organisational learning. One subproject will look at practices for event investigations and the utilisation of operational experience to assess if they support organisational learning. The second subproject will address methods and tools for organisational reviews to establish a common understanding

and agreement on criteria to be used. The final subproject will investigate safety culture of subcontracting at the nuclear power plants to identify issues for further research.

3) Tacit knowledge

Tacit knowledge can be considered critical for three reasons

- nuclear technology is complex
- nuclear know-how is only in the hands of a few,
- safety and quality of plant operation is essential.

The project focused on two main topics

- defining tacit knowledge in nuclear power plants,
- developing practices for preserving and sharing tacit knowledge.

In the new programme this research will be followed up with an investigation of expert work in safety critical environments. This project will look at processes connected to the management of human resources to identify challenges in their development. These challenges include, but are not restricted to, recruiting, career planning, knowledge and competence development, job content, etc.

4) Risk informed safety management

An earlier project aimed at risk informed decision making will in the new programme be expanded considerably. A subproject will address more specifically human and organisational factors. During 2007 means to assess human reliability in specific decision making situations will be investigated using simulators and in 2008 these studies will be expanded to cover also organisational influences on performance shaping factors.

B. Recent research funded by SKI

A strategy for the research initiated by SKI was published in 2002 [12]. The report identifies the challenges for regulatory oversight in Sweden and develops a research strategy by which the challenges can be met. The analysis highlighted management, control and organisation as one area that, where additional research efforts would be needed. As compared with the Finnish research in nuclear safety, the corresponding publicly funded research in Sweden is more oriented towards regulatory needs.

1) Operational readiness verification (ORV)

During the years 1995-1998 nine ORV events occurred in Sweden. These events focussed the attention of both the utilities and regulator in Sweden of the importance to ensure operational readiness before the plants are started up. One large study in this area was reported in the beginning of the year 2006 [3].

2) Control room philosophy

Control room design was identified already more than thirty years ago as one important issue in nuclear safety. A recent report of SKI investigated the work in control rooms to identify important factors to be considered in control room design [13]. Another study [5] made an overview of control room modifications at Swedish nuclear power plants. This interest in an earlier well researched issue should be seen in the context of the upcoming plant modernisations in Sweden.

3) Process management

Management systems are today often advocating a process orientation in work control. The Swedish nuclear power plants initiated a gradual change towards these concepts in the late 1990ies, which explains the regulatory interest in the concept. A recent report placed process orientation in relation to nuclear safety and made some recommendation for regulatory strategies [11].

4) Assuring competency

Many nuclear power plants in the world face a generation change, where the people who took the nuclear power plants into operation have been or will be retired in a few years to come. International studies have identified the issue and regulators have issued various ruling connected to the issue. The purpose of the study [2] was to make an overview of how countries regulate competence, staffing and education in the nuclear industry.

5) Plant modernisations

Operational experience shows that changes and modifications may lead to safety significant events. SKI reviews aspects of Man-Technology-Organisation of nuclear power plants involved in modernisations of plant systems and control rooms. The research [7] was initiated to demonstrate which, and to what depth, MTO aspects should be reviewed during a modernisation of and old plant.

6) Regulatory oversight

There is a large variation in strategies and practices of regulatory oversight in the world. In view of the fact that nuclear power plants are internationally owned and that they are producing electricity that flows over national borders variety creates confusion. In Europe the Western Europe Nuclear Regulators Association has taken steps to create a better harmonisation of the requirements. SKI initiated a study [6] to investigate experiences from different regulatory strategies in six countries.

7) Economy and safety

The balance between economy and safety in the decision making at the nuclear power plants has been discussed at length at different occasions. To address this question SKI commissioned a study to investigate how the three license holders in Sweden have integrated this balance into their decision making [15]. The study provided deeper insights into the management systems that are in use at the three sites.

8) Contractor activities

Nuclear power plants use contractors extensively during their annual refuelling outages and in their plant modifications. An increased use of contractors has initiated regulatory concerns in many countries. The objective of the study [1] was to assist SKI in the regulatory analysis of the safety management of contracting at Swedish nuclear power plants.

IV. EMERGING ISSUES

The nuclear industry has over the years created a good understanding of the technical aspects of safety. The understanding of human and organisational factors in nuclear safety is far more rudimentary. Therefore most important issue is this understanding can be facilitated. One important component is to create an awareness of how organisational deficiencies may impact safety. If such awareness is combined

with the understanding of the business risk of being unsafe it should be possible to initiate a change.

A. Assessing safety

Efforts to build safety into systems always rely both on some initial safety assessment, which is updated with operational experience. Many proposals have been made for methods and tools to assess safety, but reliability and the validity of suggested methods can questioned. Another problem is to select the scope and detail of the assessment to be made. A broad scope and a large detail can make an assessment very expensive, but a superfluous assessment may not be able to identify important deficiencies.

1) Safety indicators

There have been long discussions on the need to define a suitable collection of safety indicators that can be used to give a rapid assessment. In a discussion of possible leading and lagging indicators, no definitive answer has been possible to give. Similarly very little guidance on how to combine objective and subjective indicators have been given.

2) Self-assessments

Safety assessment should evidently to a large extent be carried out by the organisation itself, but again not much guidance has been given. From a regulatory point of view an interesting question is what value a self-assessment can be given as an evidence for safety.

3) External reviews

Self-assessments have always to be combined with external reviews, but how should they be carried out to provide the best value. External reviews can be carried out as peer reviews or as comparisons to a selected safety norm, but very little is known about what could be expected to give the best result.

B. Control of organisations

Control of organisations is carried out by people and through people. The behavioural sciences have given an understanding of mechanisms that govern individual behaviour and behaviour in groups of people. That understanding is presently at a level that makes it very hard to apply in generating a better understanding for important issues in the control of high reliability organisations.

1) Management systems

Management systems can metaphorically be seen as the software of organisations. Today large and integrated management systems have been built, but there still seems to be a large lack in an understanding of the factors that make the management systems used.

2) Applying operational experience

It is a well understood fact that operational experience has to be used to ensure organisational learning. Evidence from practice tends however to indicate that the same signals of certain deficiencies seem to repeat themselves, which is an evidence that organisations are poor at learning from experience. Reasons for this difficulty close the loop from operational experience to sustainable improvements may include difficulties to communicate the findings to managers that have a possibility to influence the situation as well as difficulties in finding co-ordinated solutions to the identified problems.

3) Organisational resilience

Organisational resilience has been a concept, which has got an increasing attention recently. It is not completely clear how this concept should be reflected in organisational design, but it certainly implies delegation, empowerment and an ability to set realistic, but still challenging goals for the organisation.

4) New organisational structures

The deregulation of the electricity supply forced nuclear power plants to be more effective. Decreased cost was obtained by cuts in the personnel, but to be sustainable they should be followed up better work practices. Some organisational innovations have been tried at the nuclear power plants, but according to present indications more seem to be needed.

V. Analysis and synthesis

Safety builds on consecutive rounds of analysis and synthesis. In the analysis path threats are identified and assessed to be acted on in a synthesis path, where the threats are removed, controlled or mitigated. The analysis and synthesis builds on models of how the technical, human and organisational parts of the systems functions in various conditions. To improve safety it is necessary to improve the predicting power of these models.

A. The construction of safety

1) Basic safety principles

The basic safety principles such as defence in depth and independent barriers have successful been applied for the technical systems. In principle, however, the same concepts should be possible to use also for the human and the organisational systems. Suggestions in these directions have unfortunately been scarce.

2) Aspects of safety

The last years have seen a broadening of the safety concept to include aspects such as

- nuclear safety,
- occupational safety,
- environmental safety,
- security.

All these aspects should be reflected properly in the management systems. If these areas are overseen by different authorities it would be important that the oversight processes have similar philosophies.

3) Combining deterministic and probabilistic reasoning

Risk based reasoning has been applied during the last years, but the efforts seem to be restricted to the technical systems. An explicit consideration of deterministic and probabilistic safety criteria to be applied also for the human and organisational system could provide a base for risk informed reasoning also in these areas.

B. Regulatory oversight

Presently there is a large diversity in national regulation in the nuclear field. This is understandable because the regulation reflects traditions and views that are nationally anchored. It is

however more difficult to understand the differences in the more detailed regulatory requirements, because they should be based on technical and scientific considerations. In Europe a better harmonisation is expected to be achieved through the activities within the WENRA activities.

Regulation builds on the principle that the licensee has an undivided responsibility for safety. This means in principle that the regulator should never take any control of how the work is organised at the nuclear power plants. Similarly a licensee should never as for solutions that the regulator would find acceptable. A clearer understanding of the do's and the don'ts of these two roles and their implications would be helpful.

Regulatory authorities should like any other organisation engage in strategic planning of their activities. This means that they should analyse the impact of their regulatory oversight to enter a path of continuous improvements [8].

VI. A RESEARCH AGENDA

It would be important to collect issues connected to organisation and management into some kind of research agenda. To make it possible to encourage a broad international participation it would be necessary to direct such an agenda towards the midfield issues, i.e. issues that would be of interest both for the regulators and the licensees. Presently it seems that publicly funded research has a clear bend towards regulatory interests, which means that it is less relevant for the nuclear utilities.

Still it would be beneficial if the nuclear utilities could have a larger interaction with each other and with their regulators especially in areas that are relevant for safety. If such a co-operation could be built it may provide a counterforce to the commercial interests that have decreased utility co-operation in various areas of safety.

VII. CONCLUSIONS

Human and organisational factors have a clear influence on nuclear safety and economy. There are plenty of examples where misdirected changes have hade a very large impact either as incident with safety implications or simply as lost production. If managers could be given a better understanding of the economic risks connected to human errors and organisational deficiencies, they may be more willing to invest in research in the area. It is not only necessary to do things right, but also to do the right things.

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